AUG 25 1939

PERIODICAL ROOM
LIBRARY

THE SEPTEMBER SCIENTIFIC MONTHLY

Edited by

J. McKEEN CATTELL, F. R. MOULTON AND WARE CATTELL

CONTENTS

THE CHEMICAL INDUSTRY AND THE ECONOMIC SYSTEM. DR. HAROLD G. MOULTON 197

THE FOURTH KINGDOM. DR. E. B. BENGER 204

SCIENCE AND THE WORLD OF TO-MORROW. DR. ROBERT A. MILLIKAN 210

SEA FLOORS OF GLACIER NATIONAL PARK. DR. CARROLL LANE FENTON 215

SPANISH METHODS OF CONQUEST AND COLONIZATION IN YUCATAN, 1527–1550. DR. ROBERT S. CHAMBERLAIN 227

HUMAN PSYCHOLOGY AND SOME THINGS THAT FISHES DO. PROFESSOR F. B. SUMNER 245

TIME AND PLACE FACTORS IN EARLY HUMAN EMERGENCE. PROFESSOR PAUL HUSTON STEVENSON 256

THE ZOOLOGIC DISTRIBUTION OF INTRAORAL CANCER. DR. HAYES E. MARTIN and BEULAH F. HOLLAND 262

LOOKING FOR AN HONEST MAN. PROFESSOR A. A. LEWIS 267

BOOKS ON SCIENCE FOR LAYMEN:

A Way to Utopia; Food from the Wild; What is down Below; Accent on Oddity 276

THE PROGRESS OF SCIENCE:

Chicago Cosmic Ray Symposium; The Stanford University Symposium on the Cell and Protoplasm; The Centenary of T. J. Burrill; The Seventh Assembly of the International Union of Geodesy and Geophysics; The William Bowie Medal; Spectroscopy in the Region of Radio Frequency 280

Published for the

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

SMITHSONIAN INSTITUTION BUILDING, WASHINGTON, D. C.

by THE SCIENCE PRESS

LANCASTER, PA.—GRAND CENTRAL TERMINAL, N. Y. CITY—GARRISON, N. Y.

NEW BOOKS OF SCIENTIFIC INTEREST

An Introduction to Modern Geometry. L. S. SHIVELY. Illustrated. xi + 167 pp. $2.00. Wiley.

An attempt has been made to select material developed since the time of Euclid for a textbook for a college course in modern geometry and for the preparation of teachers in high-school mathematics. A fair degree of mathematical maturity on the part of the student is desirable.

Applied Acoustics. H. F. OLSON and F. MASSO. 2nd edition. Illustrated. xviii + 494 pp. Blakiston.

A discussion of the recent developments of laboratory technique and equipment in applied acoustics. The essential parts of the theory are presented to guide experimental work. It is assumed that the reader is acquainted with the electric circuit theory.

Chemical Spectroscopy. W. R. BRODE. Illustrated. xi + 494 pp. $5.00. Wiley.

This volume is intended to supply spectroscopic information to chemical workers, and also to serve as a textbook. A set of twelve experiments on the application of spectrographic methods follows the theoretical discussion.

Geology and Engineering. R. F. LEGGET. Illustrated. xviii + 650 pp. $4.50. McGraw-Hill.

Written from a practical, engineering point of view, this book presents a review of the application of the science of geology to the whole field of civil engineering. The author is an engineer, with additional training as a geologist.

Physico Chemical Experiments. R. LIVINGSTON. Illustrated. xi + 257 pp. $2.25. Macmillan.

This book is written for the student to help him to become familiar with many of the commoner types of apparatus, to achieve some competence in the simpler techniques, and in general to illustrate the basic principles of physical chemistry.

Bio-Ecology. F. E. CLEMENTS and V. E. SHELFORD. Illustrated. vi + 425 pp. $4.50. Wiley.

A correlation of plant and animal ecology in ten chapters: Nature and Relations of Bio-Ecology; Community Functions; Reaction; Coaction; Aggregation, Competition, and Cycles; Migration; Climax and Sere; The North American Grassland; Aquatic Climax and Marine Biotic Communities.

Man Against Microbe. J. W. BIGGER. Illustrated. 304 pp. $2.50. Macmillan.

This book written for the layman is divided into three parts: The Meaning of Microbiology, The History of Microbiology, and Microbiology and Mankind. The greater portion of the book deals with the warfare between disease-producing microbes and the human race.

Fundamentals of the Petroleum Industry. D. HAGNER. Illustrated. xvii + 445 pp. $3.50. McGraw-Hill.

A textbook on the occurrence of oil and its geology. It discusses the methods of geological exploration, factors in oil production and other information about the value of geology to the oil business.

Applied Silviculture in the United States. R. H. WESTVELD. Illustrated. vii + 567 pp. $5.00. Wiley.

The silvicultural methods given in this book are applied directly to specific conditions found in the various important forest regions of the United States. Detailed information is given on the reproduction requirements of important trees.

Pneumonia with Special Reference to Pneumococcus Lobar Pneumonia. R. HEFFRON. Illustrated. xvii + 1086 pp. $4.50. Commonwealth Fund.

This treatise presents a review of investigations dealing with the inciting agent, lesions produced, clinical aspects, factors influencing recovery, prevention and treatment, and results of specific serum treatment in a large series of collected cases.

Teaching Nutrition in Biology Classes. N. E. BINGHAM. Illustrated. viii + 117 pp. $1.85. Teachers College, Columbia University.

This experimental investigation of high school pupils in their study of the relation of food to physical well-being, studies and defines adolescent needs; suggests to the teacher; describes problems, activities and assignments; presents the tests, and analyzes the statistical data derived from them.

Turtles of the United States and Canada. C. H. POPE. Illustrated. xviii + 343 pp. $3.75. Knopf.

This book, written for the layman, is an account of the sixty-three known American turtles. It is primarily about the habits of turtles, but includes keys and diagnostic descriptions, and fully presents their life histories.

Darwin. J. HUXLEY and J. FISHER. Illustrated. 151 pp. $1.00. Longmans, Green.

This book presents in modern terms the translated views of Charles Darwin and his theory of evolution in a way that lay readers may understand and that evolutionary biologists may reread with profit.

Lifelike Portraiture with Your Camera. W. H. DOERING. Illustrated. 108 pp. American Photographic.

A book for the amateur photographer with chapters on every phase of the subject. It devotes space about equally between the actual taking of the portraits and the equipment and materials used in photography.

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1939

THE CHEMICAL INDUSTRY AND THE ECONOMIC SYSTEM

By Dr. HAROLD G. MOULTON

PRESIDENT, THE BROOKINGS INSTITUTION

CHEMISTS are of course primarily interested in the development and the successful operation of the chemical industry. As a professional student of economics, I am primarily interested in the development and the successful operation of the economic system. Chemists are also interested in economics because the growth of the chemical industry depends upon the successful operation of the complex economic system of which it is an integral part. Similarly, economists are interested in the organization and conduct of the chemical industry because it is a highly important division of the economic system.

FUNDAMENTAL FACTORS AND INTERRELATIONSHIPS

As a background for this discussion, it will be useful first to orient our thinking in very fundamental terms. Economic progress depends basically upon the combined influences of the following factors: Natural and human resources; scientific discoveries; inventions; engineering applications; business organization and management; the economic system; and the governmental system. Scientists, inventors, engineers, business managers and professional students of economics and government are, in final analysis, cooperating in a common objective—that of increasing the capacity of mankind to satisfy their wants.

Each of these groups naturally thinks of itself as of primary importance, but the sanest conception is that every one of them is essential. Scientific discoveries would not yield practical results if we did not have invention; patented technological apparatus and devices would be impotent were it not for engineering applications to productive processes; engineering can function only in conjunction with a business enterprise which appraises favorably the feasibility of the development in relation to other factors of production and the potentialities of profit and loss. The individual business enterprise in turn will be thwarted if the economic system is defective; and the functioning of the economic system is dependent upon the character of the governmental organization which has been developed.

As a result of a combination of developments, which can not here be summarized, these various elements in the situation came to work together so effectively as to give us a century or more of phenomenal progress. In the course of the nineteenth century, the population of Great Britain, for example, increased from 10½ millions to 37 millions, while at the same time the standards of living rose approximately

four-fold. In the United States between 1850 and 1930 the population increased from 23 millions to 123 millions; meanwhile, the per capita production rose nearly three-fold. Scientific discoveries, inventions, engineering, effective business management and a successfully functioning economic and governmental system combined to produce a truly golden age.

In recent years, however, men everywhere have been profoundly concerned over the future. For a combination of reasons we have had for a decade a cessation of economic advancement; indeed, in many places there has been economic retrogression. This arresting, not to say ominous, development compels us to reexamine fundamentals. Scientists feel a sense of frustration; inventors secure patents which run to waste for lack of commercial development; opportunities for engineers are restricted; business is physically depressed, and business men are spiritually demoralized; economists are perplexed; and government officials are both confused and apprehensive.

The Operation of the Economic System

Where is the source of difficulty in the complex process to which we have referred? Is there something inherently defective in the economic system, or has it merely been operated badly? It must be borne in mind that under a system of individual business enterprise the economic system is operated by business managers in quest of profit. I wish, therefore, to review the basic principles involved and the procedures which must be followed if the economic system is to perform satisfactorily its essential function of producing and distributing an abundance of goods and services. The incentives for business enterprise and the mechanisms by which the system of private business enterprise is supposed to be operated have often been expounded by both professional economists and business leaders.

First, it is contended that each business manager naturally stands to gain by increasing general over-all efficiency and thereby reducing costs of production. He may accomplish this result by the construction of a larger and more efficient plant, by the installation of better equipment, by the introduction of superior internal management, by improved methods of marketing, by integrating various stages in the productive process, or by a combination of various methods.

Second, having reduced costs of production, the business manager is in a position to increase his profits in one or the other of two ways: He may continue to sell at the same price as before, enjoying the advantage of a wider margin between cost and selling price, or he may expand the volume of his business by means of price reductions. It is reasoned that since the increase in efficiency which is responsible for the reduction in costs commonly involves an expansion of productive capacity, and since the maximum economies can be obtained when operating at full capacity, the greatest profits will result if sales are expanded by means of a reduction of prices. In short, increased efficiency makes possible lower prices, and the profit incentive leads to actual reductions of prices.

Third, the process naturally involves the continuous elimination of obsolescent or otherwise inefficient equipment and establishments. The industrially fit, as gauged by ability to sell at a minimum price, alone survive; moreover, the efficient of to-day often become the inefficient of to-morrow. A particular business man, firm or corporation may survive over a long period of years, but only if the production methods employed keep always abreast of changing times.

It is clear that with a system thus operating the standards of living would steadily rise. The progressive reduction of prices as efficiency increases would, of course, constantly increase the purchasing power of the masses, giving them an

increasing volume of goods for the same money.

It should be carefully noted that this theory of progress implies that the reduction in money costs must result from increased efficiency rather than from a mere reduction in money wage rates. A reduction in wage rates may indeed lower money costs and prices; but since such a reduction increases neither efficiency nor the purchasing power of the masses, there is no resulting economic advancement.

In order to reveal more distinctly what is involved in raising living standards in a *pecuniary* society, I state explicitly two principles as follows:

First, *the process of raising the standard of living of wage-earners necessarily involves increasing the spread between wage rates and prices.* That is, a wage-earner can increase the volume of his purchases from year to year only if wage rates are increased relatively to the prices of the commodities which he buys. If he gets more dollars and prices remain unchanged, his purchasing power is expanded; if he gets the same number of dollars and prices decline, his purchasing power is expanded. There are, of course, other possible combinations of changes in wages and prices, but the purchasing power can not be expanded unless the spread between wages and prices is increased.

Second, *an increasing spread between wage rates and prices depends fundamentally upon increasing the efficiency of production.* While minor and temporary increases in wages may sometimes be achieved by trenching upon profits, a progressive increase in the wage-price ratio depends directly upon the acceleration of technical advancement, improved management, increased labor efficiency, etc. Any practices or policies that tend to work in this direction are economically sound; those which work in the opposite direction are economically unsound.

The Role of Chemistry

It is superfluous for me to attempt to instruct chemists about the significance of chemistry and the chemical industry. But since many chemists are specialists, deeply immersed in particular aspects or divisions of chemistry, it may be useful even for them if I summarize some of the development which has occurred in the industry as a whole during the past fifteen years. I shall not, of course, presume to say anything about the significance of individual chemical products or particular divisions of the industry; my comments will relate simply to the industry as a whole.

The fundamental significance of the chemical industry lies in its permeating influence. Chemistry is not merely a new industry which has added an important series of new products for human consumption. It is an industry, the achievements of which profoundly affect the productivity of many other industries; indeed, its influence ramifies throughout the economic system. Chemistry is *creative,* to use Slosson's phrase, not only in the sense that it involves both *analysis* and *synthesis,* but also in that it yields practical results of great utility.

Its primary *creativeness* lies in its fructifying influence. Chemistry cuts across and underlies so many productive processes that the term *fundamental* is truly descriptive of its significance. As the *science of the transformation of matter,* it not only relates to nearly every aspect of our lives from birth to death, but, as Stieglitz has written, its

> wizardry permeates the whole life of the nation as a vitalizing, protective and constructive agent very much in the same way as our blood, coursing through our veins and arteries, carries the constructive, defensive and life-bringing materials to every organ in the body. . . . It makes possible scientific control of such widely divergent national industries as agriculture and steel manufacturing. It governs the transformation of the salts, minerals and humus of our fields and the components of the air into corn,

wheat, cotton, and the innumerable other products of the soil; it governs no less the transformation of crude ores into steel and alloys, which, with the cunning born of chemical knowledge, may be given practically any conceivable quality of hardness, elasticity, toughness or strength. And exactly the same thing may be said of the hundreds of national activities that lie between the two extremes of agriculture and steel manufacture!

From the strict economic point of view the basic significance of chemistry is found not only in the wealth of new and important products that it has created, but also in the way in which it has affected efficiency and costs of production in the varied industrial fields to which it contributes. By developing new methods which improve the efficiency of production, as well as the quality of products, chemistry is cumulative in its influence. While we can not trace these effects in detail, it is possible to measure the achievements of the industry by analyzing its growth and its contributions to society as a whole in terms of available data respecting productivity in relation to prices, wages and profits.

During the course of the past fifteen years the prices of chemical products as a group have declined about 16 per cent. Drugs and pharmaceuticals as a group show a substantially greater decline, amounting to about 22 per cent., while the prices of fertilizer materials decreased as much as 30 per cent. These declines may be compared with a decrease in the average prices of manufactured products as a whole of about 12 per cent.; and with a decrease in the average prices of all commodities, including agricultural and raw material products, of about 19 per cent. Thus, viewed from the standpoint of price reductions, the showing of the chemical industry is distinctly better than the average of American industry.

We may examine next the wages paid in the chemical industry as compared with manufacturing as a whole. Between 1923 and 1938 *total* wage disbursements in the chemical industry increased approximately 30 per cent.; *hourly* wages increased 31 per cent. Meanwhile, in manufacturing as a whole total wage disbursements declined by approximately 10 per cent., though hourly wages increased by about 15 per cent.

Employment in the chemical industry has expanded materially during the course of the past fifteen years. Comparing the three years 1923 to 1925 with the three years 1936 to 1938, we find that employment has increased nearly 25 per cent. This is in sharp contrast with the trend of manufacturing industry as a whole, where the total number employed has declined by approximately 1 per cent. These employment figures indicate both that the chemical industry has been undergoing rapid growth and also that the improvements in productive efficiency which have occurred have not been at the expense of labor. As we have seen, the number of workers employed has increased materially, and wages have risen substantially. At the same time, in so far as workers in the chemical industry are consumers of chemical products, they have benefitted by products of improved quality sold on a gradually declining price basis.

These developments have of course been made possible by a constantly increasing volume of investment in the industry and by an increased productivity resulting from technological developments. In the past 15 years the fixed capital investment of the four largest chemical companies has nearly doubled. As an accompaniment to this expanding investment, together with improvements in management, productivity has greatly increased. The output per man hour has in fact increased by approximately 75 per cent.

The return to stock owners has been unusually satisfactory. During the past 15 years dividends have ranged from 5.6 to 13.5 per cent. on the book value of

the stockholders' investment. Payments were maintained at a high level during the depression years.

It is of interest that the investment in the chemical industries of the United States now exceeds 4 billion dollars, and is equal to about 7 per cent. of the investment in all manufacturing enterprises. Measured by the value of the sales, the chemical industry now ranks third in the United States, being exceeded only by metals and metal products and food and kindred products, which represent broad industrial classifications.

The achievements of the chemical industry in recent years may be summarized as follows:

Expanding capital investment and increasing efficiency have made possible a reduction of prices; an increase of wages, both hourly and aggregate; an increase of employment; and a comparatively high level of profits. At the same time there has been a great improvement in the quality and variety of products, some of which minister directly to the satisfaction of human wants and others of which contribute to increasing efficiency in a wide range of other industries.

Requirements for the Future

At the present time, as every one is aware, grave fears are entertained by many with respect to the future of the economic system in this country. In recent years the view has been widespread that we have had so much scientific and technological advancement that we are menaced with over-production and that in consequence we must expect the rate of industrial progress to be severely curtailed.

It is of interest to note for purposes of comparison that fifty years ago similar fears were expressed with respect to a great increase in productive capacity. In the middle eighties an eminent economic writer, David A. Wells, attributed the great depressions of trade in the seventies and eighties to the fact that "the supply of the great articles and instrumentalities of the world's use and commerce has increased, during the last ten or fifteen years, in a far greater ratio than the contemporaneous increase in the world's population or of its immediate consuming capacity." Carroll D. Wright, in an official government report in the late eighties, expressed a similar concern over the lack of investment opportunities and employment possibilities. He wrote:

> The rapid development and adaptation of machinery have brought what is commonly called "over-production." The nations of the world have overstocked themselves with machinery and manufacturing plants far in excess of the wants of production. The day of large profits is probably past.

Nevertheless, in the following forty years we experienced the greatest period of technological progress and industrial expansion in our history. There is no more reason for assuming in the late 1930's that we have reached the end of industrial progress than there was for the same assumption in the late 1880's. The income of the American people is still far below the requirements for satisfactory standards of living. In 1929, the year of our greatest production, the total national income was about 81 billion dollars, or the equivalent of about $660 per capita—$2,600 per family. Twelve million families, or 42 per cent. of the total number, had incomes of less than $1,500; and 60 per cent. of the families had incomes of less than $2,000. At 1929 prices, a family income of $2,000 was sufficient to supply little more than the basic necessities required for health and efficiency; generally speaking, it provided no margin for comforts and luxuries of life. Budgetary studies indicate that the provision of "reasonable standards of living" would require an income nearly double that received by the masses of the American people in the year of our greatest production.[1]

[1] "America's Capacity to Consume," The Brookings Institution.

In the years that have elapsed since 1929, however, there has been an actual curtailment of national productive capacity, while at the same time we have had a further increase of population of more than 7 per cent. Per capita production in 1937—the best year of the recent recovery movement—was only about 85 per cent. as great as in 1929. The available income was only a little over $500 per capita. So long as the great masses of our people have vast unfulfilled desires we should obviously continue to increase productive efficiency in order to raise the standards of living.

Is There Room for Expansion?

We may also consider still another argument that has been advanced in support of the view that the era of industrial expansion has ended and that improvements in living conditions in the future must necessarily be at a very much slower rate than in the past. A number of factors and considerations lie behind this conclusion, the principal ones of which are: The disappearance of the frontier; the substantial completion of the building of our great industries, with no significant new ones in sight; and the declining rate of population growth, forecasting a stationary population in the not distant future. The severe and persistent character of the great depression which began in 1929 is also regarded as evidence that fundamental changes in the American economic scene have already occurred. This conclusion is perhaps a natural outgrowth of the prevailing character of American economic development over the course of the past century.

We had vast unsettled areas and unexploited resources; we had a rapidly expanding population, resulting both from a high birth rate and large immigration; and we built a never-ending series of new industries—railroads, public utilities and manufacturing enterprises of every description. In the light of this history and of the recent period of stagnation, it is easy to understand how it might appear on first thought that our future, so to speak, lies behind us.

A factor of vital importance has, however, been overlooked in this line of reasoning. Before looking forward, let us look backward for a moment and examine the sources of expansion in the past. Economic activity—the use of our labor power and our capital equipment—has always been directed to a double purpose: the production of goods to care for the needs of increasing numbers of people; and the production of increasing quantities of goods to meet the growing demands of the existing population. Stating the matter in other terms, we not only seek to produce enough to provide our children with necessaries, but we hope to enable them, as well as ourselves, to enjoy higher standards of living than were attained by our predecessors.

We may translate these general statements into specific terms by reference again to what actually occurred in the great era of expansion from 1900 to 1929. We did, it is true, devote our energies to the production of primary goods and services for a steadily expanding total population, but at the same time we were constantly producing more for the already existing population. In the course of this thirty-year period as a whole, *per capita* income rose almost 40 per cent.

Is it not obvious that a cessation of population growth does not render it necessary for us to refrain henceforth from producing more and yet more for the existing population? Are not the unfilled wants and unsatisfied desires of the present 130 millions of people just as real a source of potential demand as the elemental needs of those who may be born in the years ahead? The *character* of our productive output might differ in considerable degree, but the

total output need not be affected—that is, not until our desires are fully satiated. Studies indicate that we need have no concern on this score until the national income is at least three times its present level. We have been accustomed to thinking of expansion in terms of frontiers, geographic areas and numbers of people—that is, in *extensive* rather than *intensive* terms. Hence we are prone to overlook the vast potential markets that may be opened on the intensive frontier of development.

If we are to expand this frontier and realize progressively higher standards of living—and, in the process, furnish increasing employment for both labor and capital—we must—as I have already indicated—operate the economic system on sound principles. I close with a re-emphasis of the underlying requirements for continued progress.

There must be constantly increasing efficiency in production on the part of both labor and capital. Only by everlastingly improving technical processes and lowering the costs of production can we obtain progressively higher standards of living. To try to accomplish this result in any other way means simply tugging in vain at our collective boot straps.

As efficiency is increased, the benefits must be broadly disseminated among the masses by means of high wages, low prices or a combination thereof. This is essential for a double reason:

First, it is a fundamental requirement for social and political stability and the well-rounded growth of a democracy. It is doubtful indeed if any economic or political system can permanently maintain itself unless it does maintain the goal of the greatest good for the greatest number.

Second, a broad dissemination of the benefits of technical progress is necessary to provide the market demands for an expanding industry. Under our capitalistic system we produce to sell goods in the market. If we increase capacity to produce without correspondingly increasing the capacity of the masses to purchase, we simply reach an impasse. Production schedules have to be restrained, with an accompanying retardation of the rate of economic progress.

Industrial growth, development, progress, require the expansion of consuming power step by step with an expansion of producing power. To put the matter in very simple terms: Healthy growth in the economic organism, like healthy growth in any other organism, must proceed from the deepest and broadest possible rootage. It must rest on the expanding well-being of the entire population.

THE FOURTH KINGDOM

By Dr. E. B. BENGER

GENERAL ASSISTANT CHEMICAL DIRECTOR, E. I. DU PONT DE NEMOURS & COMPANY

At the dawn of history, we find man employing for all his needs materials as supplied by nature. Man secured food from plants and animals; clothing came from the same sources; and shelter was commonly afforded by a convenient cave. For thousands of years, nature, almost unaided, supplied man's primary needs.

Little by little, man learned to modify natural products. He chipped sharp instruments and deadly weapons from rock; he fashioned knives from naturally occurring metals, such as copper; he learned to weave rude fabrics. Probably through accident, glasses and metallic iron were found in the ashes of fires. Such discoveries perhaps marked the beginning of a new era. But progress was painfully slow. At times, nature seemed niggardly indeed in supplying the necessary materials for life and safety. Famine was not uncommon; pestilence and disease often took thousands of lives. As man became better organized in social and political units, the deprivations, sufferings and the need for better things, and more of them, led to taking these things from others by force.

The acquisition of territory by force and by threat of force is not unusual in the world history. In fact, ever since the days of Alexander the Great, kings and emperors have expanded their empires through military conquest. This has, of course, chiefly been for the purpose of gaining additional materials—gold, cattle or grain. We have seen a number of such conquests even in the last few years. Even we, here in America, may have been guilty of acquiring valuable property through military aggression.

But America has acquired peaceful habits. This has come about, partly at least, from the fact that we have not been forced to provide our needs by conquest. America has obtained products of more enduring value than were ever won by Alexander or Cortez or Pizarro, and without the use of swords, guns or poison gas. These products, which have increased our national wealth by untold millions, have become available through the peaceful conquest of matter. This conquest has been without wide-spread suffering or death; it has, on the contrary, created new industries, opened up millions of jobs, and made life happier and safer for all.

We were taught in school that there are three kingdoms of matter—the animal, the vegetable and the mineral. More recently, we have come to look upon the substances from the three natural kingdoms as raw materials rather than as finished products. We are still largely dependent upon animals and vegetables for food, and from the earth we still take metals, coal and other valuable minerals. Many of these things are still employed more or less as nature provides them, but this is only because we have not yet been able to improve upon many of nature's products. We can not now offer more tender and juicy synthetic beefsteaks or a more beautiful man-made rose!

The fourth kingdom, of which I shall speak to-day, has, however, become firmly established, and the products of the fourth kingdom, made in turn entirely from the animal, vegetable and mineral kingdoms, now supplement the products from the three original kingdoms themselves.

The conquest of the fourth kingdom was slow in getting under way. It is far from complete now, after a century of incessant and increasing attempt. Possibly we can say that inroads on the new kingdom began in 1828, when Wöhler synthesized for the first time an organic material occurring in nature, namely, urea. Until that time it was believed impossible ever to produce artificially the products produced by animal or vegetable life. Wöhler's disproof of this theory may be taken as the first stroke in the conquest of the fourth kingdom.

About thirty years after Wöhler, a young British chemist, Perkin, undertook to synthesize quinine. He failed, but, as is often the case in an experimental work, achieved a result of greater importance than the one he sought. He didn't get quinine, but he made the first synthetic coal-tar dye. We can still get natural quinine in quantity, but we wouldn't want to do without the thousands of synthetic colors which brighten our lives.

With these simple beginnings, it became apparent that nature's products could be employed in the construction of entirely new compositions, which in turn could be used in countless ways. The conquest of the new kingdom, the chemical kingdom, then was undertaken more earnestly. To-day, the conquest is carried on by an army of 32,000 research workers in over 1,700 laboratories in the United States. The maintenance of the army costs $250,000,000 a year, which, after all, represents a very cheap campaign; in fact, not as much as we spend on cosmetics.

I shall now mention some of the materials which we have acquired by the conquest of this new kingdom.

The textile industry is a very old one, dating back to the earliest records of man. For four thousand years no new textile fiber appeared. You are familiar with the amazing development of the synthetic yarn, rayon, which in the last two or three decades has sprung into being and grown so fast that now seven times as much rayon as silk is used in America. This rayon, made from the cellulose of cotton and wood, has been dependent upon the vegetable kingdom for its basic material. But recently, you have heard that an entirely new fiber, dependent only upon the mineral kingdom, has been made. I refer to nylon, a name coined for a family of new synthetic compounds. Nylon has a structure somewhat like that of proteins, and from it can be spun filaments of extreme fineness, stronger and more elastic than any of the natural fibers. Probably the most important of the early uses for nylon will be in women's fine hosiery. It is also hoped, however, that dress goods, gloves, draperies and upholstery may be produced from this new synthetic product.

Incidentally, from nylon we already have available the new "Exton" bristle for use in toothbrushes. These bristles are more durable, soften less when wet, and do not shed. From bristle-like materials we also have fishing leaders and fishing lines.

I mentioned Perkin's discovery of mauve. Previously the textile industry was entirely dependent upon vegetable and animal colors. These natural dyes were limited in number and in many cases the fabrics colored with them were dull and faded when washed or exposed to light. Furthermore, many of the natural dyestuffs were very expensive. The Tyrian purple of Biblical times was obtained from a shell-fish found in the Mediterranean, and purple woolen fabrics were so costly that they could only be bought by kings and nobility; hence the term "royal purple." To-day, the chemist makes a complete rainbow of bright, fast colors from coal tar, far exceeding in brilliance and permanence the royal purple of antiquity, and at a cost so low that colors are abundant in even the poorest of our homes.

The modern textile industry could not exist without the dyestuffs and fibers of the fourth kingdom.

Many accessory textile chemicals have also been made synthetically. Thus fabrics are made more resistant to creasing and wrinkling and more water-repellent and freer from spotting by rain because of chemical treatments. We also have the new "soapless soaps," which work as well in hard water as in soft water, and wetting agents to speed up the bleaching and dyeing operations—agents so potent that water to which a small amount has been added will actually cause a duck to sink. We have effective moth-repellents, mildew inhibitors and a new chemical which renders fabrics flameproof.

From the mineral kingdom comes the coal, limestone and salt needed for the manufacture of another valuable synthetic which, strangely enough, closely resembles in certain respects an important product of the vegetable kingdom—rubber. I have reference to neoprene, the man-made rubber-like material, which, although similar to natural rubber in elasticity, toughness and strength, is wholly different in chemical resistance. Whereas rubber is attacked and destroyed by oils and greases, neoprene is resistant to them. It is because of this that neoprene, although now selling at about four times the price of rubber, is, nevertheless, finding an increasing outlet in the manufacture of such items as hose for gasoline pumps, industrial and household gloves, printing rollers, belts for conveying oily materials and numerous other purposes where rubber is inadequate. For certain of these purposes, neoprene outlasts rubber ten to twelve times or even more.

Among the hundreds of applications for this man-made rubber are some 50 uses in the automobile industry alone, including insulation for ignition cable and horn wire, shock absorber gaskets, thermostat diaphragms and water-pump seals.

Among the numerous products of the new chemical kingdom, probably none finds wider application than the man-made plastics. Supplementing and displacing such natural products as wood, metals, rubber, shellac, ivory, tortoise shell, jade and amber, the synthetic plastics find application in the manufacture of literally thousands of articles—motion picture film, automobile accessories, radio cabinets, windshields for airplanes, electrical appliances, lighting equipment, plates for false teeth, toiletware, ash trays, buttons and buckles, scuffless shoe heels and costume jewelry.

Laminated plastics, made by combining a number of sheets of plastic-impregnated cloth, paper or wood under high pressure at an elevated temperature, possess great strength, and are accordingly used in making such articles as wall board, instrument panels and gear wheels—supplementing or wholly replacing such natural materials as wood, metals and slate. In the not distant future, these laminated plastics may play an important part in the construction of automobiles and airplanes.

One of the newest plastics is "Lucite" methyl methacrylate plastic, made from coal, air and water. Because of its toughness and transparency, this new material is finding application for a variety of uses, both decorative and industrial. For example, the reflector buttons along Route 16 between Detroit and Lansing, Mich., are made of "Lucite," and during the first three months following installation of these reflectors there were 79 per cent. fewer night accidents than for the corresponding period before they were installed. Their effectiveness is shown by the fact that during the same period daytime accidents declined only 37.5 per cent.

A very recent addition to the plastics family is "Butacite" polyvinyl acetal plastic, used as the interliner in laminated glass. Because of its strength, toughness and flexibility, particularly at

low temperatures, "Butacite" makes possible the safest safety-glass ever made. At the Franklin Institute in Philadelphia a nine-ounce steel ball was dropped 85 feet onto a sheet of this new safety glass. The glass was, of course, cracked, but it did not shatter, and observers seated within four feet were in no danger from flying splinters.

Camphor is an essential part of the nitrocellulose or celluloid-type plastics used in making motion picture film and dozens of other products. For many years, this material came from the camphor trees of Formosa, an island in the Pacific owned by Japan. The Japanese controlled the world market for camphor and, with it, the price. But in recent years chemists have worked out a process by which turpentine from our southern pine trees is converted into camphor that is chemically identical with that obtained from camphor trees of faraway Formosa. To-day the du Pont Company is producing a substantial part of our total domestic consumption, and in an emergency additional plant capacity could be provided to take care of our entire domestic requirements. In 1918, the price of imported camphor reached $3.75 a pound; to-day the synthetic product sells for around 35 cents a pound. Quite a difference!

For nitric acid, nitrogenous fertilizers and other forms of combined nitrogen so essential to industry and agriculture, man was formerly dependent largely upon natural deposits of sodium nitrate in Chile. These materials are now supplied from the fourth kingdom. The chemist takes nitrogen from the air and hydrogen from water and, at an elevated temperature and tremendous pressure, forces these two gases to combine in the form of ammonia. From this ammonia is made the nitric acid needed in the manufacture of nitrocellulose for plastics, lacquers, smokeless powder and "Fabrikoid" pyroxylin-coated fabrics. Nitric acid is used also in making fertilizer chemicals such as sodium nitrate.

Another fertilizer chemical is urea, a product once obtained only from animal secretions, but now made by du Pont from coal, air and water in tremendous quantities.

In addition to its use as a fertilizer chemical, urea finds application in the manufacture of an important type of plastic which is widely used in making light fixtures, unbreakable tableware and housings for counter scales. Urea is also finding an increasing outlet in the field of medicine, to replace the maggots once used in the healing of certain stubborn infections, particularly of the bone.

Formaldehyde, made from methyl alcohol, is another important chemical used in the manufacture of plastics, in combination with urea, casein from milk or phenol from coal tar. Formerly methyl alcohol, known more commonly as wood alcohol, was obtained by the dry distillation of wood. To-day, in a plant at Belle, W. Va., the methyl alcohol used in making formaldehyde, and for a wide variety of other industrial purposes, is produced by synthesis, again starting with coal, air and water.

The farmer and fruit grower turn to the new kingdom of synthetics for improved weapons with which to combat the plant diseases and hungry insects which are responsible for losses estimated at more than three billion dollars a year. From the research laboratory have come improved insecticides, such as the new "Loro" insecticide—materials less toxic to humans than nicotine, and which unlike rotenone and pyrethrum, are based on domestic raw materials.

Whereas man formerly went directly to the vegetable and animal kingdoms for perfumes and flavors, to-day nature's products are supplemented by synthetics from a variety of sources, including malodorous coal tar. And certain odors are to be had only as synthetics—that of the

lilac, for example, which is so delicate as to be destroyed when an attempt is made to take it from the flower.

The characteristic ingredient of musk, obtained from deer that live in the lofty mountains of Tibet, would be worth some $40,000 a pound if it could be had in a perfectly pure state. But the new chemical kingdom has recently provided "Astrotone" synthetic musk, substantially identical with the characteristic ingredient of natural musk, at only a fraction of the cost.

And last, but not least, the medical profession would be well-nigh lost without the materials of the fourth kingdom. The physician and surgeon turn daily to the realm of synthetics for chemicals that nature either failed to make or to provide in quantities sufficient for our needs—anesthetics which are not habit-forming, chemicals which may safely be used for allaying fever and pain, vitamins to supplement our diet, hormones for the correction of various mental and physical disorders and drugs which are specifics for certain diseases.

Within recent years, the chemist has synthesized several of the vitamins—those materials occurring naturally in small amounts in certain foodstuffs, which are so essential in warding off rickets, pellagra and other deficiency diseases. It has recently been found, for example, that synthetic ascorbic acid is identical with Vitamin C found in fresh fruits and vegetables, a deficiency of which leads to scurvy, fragility of the bones and loosening and decay of the teeth—ills once common among sailors on long voyages.

Members of a late Mount Everest expedition took along a supply of synthetic Vitamin C instead of the large quantities of fresh fruits and vegetables which would have been necessary to supply them with an adequate amount of this highly essential vitamin.

The research chemist has established the constitution of, and synthesized, certain of the hormones, those little-understood secretions of the ductless glands, which in some mysterious way regulate the functioning of our bodies and minds. Research is constantly being directed to a better understanding of these complex, powerful chemical substances, an excess or shortage of which may determine whether we are giants or midgets, brave or cowardly, feeble-minded or possessed of a vigorous intellect.

Even the degree of one's masculinity or femininity now appears to be a matter of hormones, and recent research has shown that by the injection of a small amount of the proper sex hormone a tomcat can be made to mother a litter of kittens, and by similar treatment the gallant and haughty barn-yard rooster is transformed into the maternal-like guardian of a flock of biddies. What the future is for sex hormones no one can say with certainty, but there are indications that timid souls such as Caspar Milquetoast may be transformed overnight into Robin Hoods.

Since the advent of "Salvarsan" thirty years ago for the cure of syphilis, no synthetic chemical has met with so welcome a reception, or shown greater promise, than sulfanilamide. Although introduced into the United States only a few years ago, this new healing agent has already saved the lives of thousands suffering from "blood poisoning," peritonitis, streptococcic sore throat, childbirth fever and other dangerous maladies due to streptococcic infection.

And during the past few months a related synthetic chemical, sulfapyridine, has shown great promise in the treatment of various types of pneumonia, which claims each year a toll of some 100,000 lives in the United States.

Thus we see that the products of the new chemical kingdom minister unto our needs on every hand. Without them,

modern industry would be paralyzed, much of beauty would be gone from our lives, and living itself would be more hazardous.

Consider, for a moment, the field of transportation. To this all-important field the fourth kingdom supplies steels and other alloys without which there would be no automobiles, airplanes or modern trains. This new kingdom provides the blasting agents needed for mining the metals from which these alloys are made. It supplies the quick-drying finishes to facilitate mass production; tire fabrics of rayon which add greatly to the life of truck and bus tires on long, nonstop runs; improved fuels which made possible the modern high-compression motor; extreme-pressure lubricants essential to the hypoid gear; lead tetraethyl to prevent knocking; antioxidants for gasoline to inhibit the formation of gums which would clog up the motor and fuel lines.

From this new kingdom of synthetics come chemicals which speed the vulcanization of tires, and other chemicals which retard their deterioration by sunlight and air; the man-made rubber which serves where the natural product is unsuited; chemicals for plating; and plastics for safety glass and accessories.

And the end is not yet in sight. Where shall we turn to find the new materials demanded by an industrial and social order whose very watchword is progress?

In the field of transportation, where shall we turn to find new materials capable of standing the strain of ever-increasing speed by land, water and air?

Where will the farmer turn for still better fertilizer materials and insecticides?

Where will the medical profession turn to find a cure for cancer and like "incurable" diseases?

Where but to the laboratories of fundamental and applied research?

The unsolved problems of industry and agriculture, and the physical and mental ills for which there is as yet no cure, stand as a challenge to the research workers of the fourth kingdom, whose motto is, "We serve."

SCIENCE AND THE WORLD OF TO-MORROW

By Dr. ROBERT A. MILLIKAN

DIRECTOR OF THE NORMAN BRIDGE LABORATORY OF PHYSICS, CALIFORNIA INSTITUTE OF TECHNOLOGY

EVEN though "prophecy is the most gratuitous form of mistake," and even though there is obviously the possibility that something so completely foreign to my thinking may happen as to make any prognosis that I may hazard now look ridiculous in the years to come, yet I am going to be foolish and rash enough to forecast that, barring the return of the dark ages through the triumph the world over of tyranny over freedom, of the spirit of world conquest over the spirit of reason and peaceful change, life in America fifty or a hundred years hence will not differ nearly as much from the life of to-day as the life of to-day differs from that of a century or even a half century ago. The processes and techniques that have been responsible for the enormous changes of the last century will continue to improve our economic and social well-being, but the main changes will come from a more general understanding by the voting public of the nature of these processes and a more intelligent use of them. This will mean the gradual elimination of the effort to violate natural and social laws or, arithmetically stated, to make two plus two equal six, as we have been so ignorantly and so disastrously trying to do in much of our social floundering of recent years.

So long as one is considering only the physical or biological bases of change the informed and competent scientist has some reason for confidence in his analysis as to the general direction which progress can and must take. He at least knows a great many sorts of things that will *not* happen, and these are in the main the very things that the uninformed dreamers and wishful thinkers—the emotional pseudo-reformers, not the real ones—hope and expect to see happen. Thus, we shall never be able to transform the energy released in the burning of coal or in the absorption of the sun's rays directly and completely into electrical energy. Indeed, we shall never be able to go very much farther in this direction than we have already gone.

To-day the most efficient internal combustion engines transform into work 35 per cent. of the heat energy released in the burning of the fuel, and it is safe to predict that in continuous operation we shall never be able to make very great advances beyond this limit. By that I do not mean that through improvements in details efficiencies in the neighborhood of say 50 per cent. are completely out of the question. But in any case, the so-called second law of thermodynamics, which has now taken its place as a part of the core of established knowledge in physics, stands in the way of the realization of the dreams of the multitude of inventors and magicians who still want to transform the sun's heat rays directly and completely into work. Though the knowlege that it can not be done is less than a hundred years old, it is about as firmly established as is the law of gravitation.

I have chosen the foregoing illustration because it lies at the very base of any correct analysis of what science has done and of what it is capable of doing in the future in bettering man's lot on earth. Let us look first at what it *has* done, for this will enable us to understand better what it can do. When in 1825 my grandfather loaded into a covered wagon his young wife, his Lares and Penates and

all his worldly goods, and trekked west from Stockbridge, Mass., first to the Western Reserve in Ohio, and again in 1838 to the banks of the Rock River in western Illinois, the conditions of that migration, the motives prompting it, the mode of travel of the emigrants, their various ways of meeting their needs and solving their problems, their whole outlook upon life, were extraordinarily like those which existed four thousand years earlier when Abraham trekked westward from Ur of the Chaldees. In a word, the changes that have occurred within the past hundred years not only in the external conditions under which the average man, at least in this western world, passes his life on earth, but in his superstitions, such as the taboo on the number thirteen or on Friday sailings (why, my own grandmother carried a dried potato in her pocket to keep off rheumatism) in his fundamental beliefs, in his philosophy, in his conception of religion, in his whole world outlook, are probably greater than those that occurred during the preceding four thousand years all put together. Life seems to remain static for thousands of years and then to shoot forward with amazing speed. The last century has been one of those periods of extraordinary change, the most amazing in human history.

If, then, you ask me to put into one sentence the cause of that recent rapid and enormous change I should reply: "It is found in the discovery and utilization of the means by which heat energy can be made to do man's work for him." The key to the whole development is found in the use of power machines, and it is a most significant statistical fact that the standard of living in the various countries of the world follows closely the order in which so-called labor-saving devices have been most widely put into use. In other words, the average man has to-day more of goods and services to consume in about the proportion in which he has been able to produce more of goods and services through the aid of the power machines which have been put into his hands. In this country there is now expended about 13.5 horsepower hours per day per capita—the equivalent of 100 human slaves for each of us; in England the figure is 6.7, in Germany 6.0, in France 4.5, in Japan 1.8, in Russia 0.9, in China 0.5.[1] In the last analysis, this use of power is why our most important social changes have come about. This is why *we* no longer drive our ships with human slaves chained to the oars as did the Romans and the Greeks. This is why we no longer enslave whole peoples, as did the Pharaohs, for building our public structures and lash them to their tasks. This is why ten times as many boys and girls are in the high school to-day in the United States as were there in 1890—more than five million now, half a million then. This is why we have now an eight-hour day instead of, as then, a ten, a twelve—or sometimes a fourteen-hour day. This is why we have on the average an automobile for every family in the country. This is why the lowest class of male labor, *i.e.*, unskilled labor, gets nearly twice as much in real wages in the United States as in England, three times as much as in Germany or France, and thirteen times as much as in Russia, and this is why the most abused class of labor in the world, domestic service, is even better off relatively in this country though completely unorganized, *i.e.*, through the unhampered operation of economic laws, than is any other class of labor, skilled or unskilled.

Do not think that these are the one-sided pronouncements merely of an enthusiastic scientist. Any one can check them who will begin to study them. Listen to President Karl Compton's

[1] These figures are substantially as given in *Am. Economic Review*, 1933, p. 58, Read; and in "Toward Civilization," Hirshfeld, 1929.

formulation of the results of his similar historical studies. He says:[2]

> From the days of the cave man, all through history up to the modern era of science, there were only two primitive recipes for securing the materials desired for the more abundant life. One was to work hard and long in order to produce more, and the other was to take the good things of life from some one else, by theft, conquest, taxation or exploitation.
>
> To get the good things of life by taking them from others is a primitive instinct, undoubtedly developed by the age-old struggle for existence. We have all seen monkeys, or seagulls, or wolves, or pigs snatching food from each other, fighting to possess it, or shouldering each other away from the trough. When human beings carry this philosophy too far beyond the accepted standards, as did Jesse James and John Dillinger, we call them "public enemies." But this same philosophy of taking what we want from others, by violence and trickery, or by legalized strategy and force, has run all through human history.
>
> But, in reecnt times, modern science has developed to give mankind, for the first time in the history of the human race, a way of securing a more abundant life which does not simply consist in taking away from some one else. Science really creates wealth and opportunity where they did not exist before. Whereas the old order was based on competition, the new order of science makes possible, for the first time, a cooperative creative effort in which every one is the gainer and no one the loser.
>
> For this reason, *I believe that the advent of modern science is the most important social event in all history.* It marks the point at which men have come to understand themselves and the world they live in well enough to begin systematically to control the hidden forces of nature to their advantage. Already science has done wonders to raise the standard of living and of knowledge, but these hidden forces are so great that we are assuredly only at the beginning of things possible.
>
> Some significant facts regarding the effect of the machine on the wages and employment of the worker are these: Counting 1840 as about the year in which power machinery came to be important in the United States, we find a steady increase since that date in the ratio of average wages to average prices of commodities, so that it is now about seven times what it was in 1840. In other words, the average wage earner in America can to-day buy seven times as much with his wages as he could in 1840; or more than twice as much as he could in 1910. Also despite increasing population and increasing use of labor-saving machinery, the percentage of our population gainfully employed increased 25 per cent. between 1870 and 1930.
>
> More material progress has been made during the past one hundred and fifty years under the American system of business enterprise than during all the preceding centuries in world history. This record of achievement is a challenge to those who would radically change that system. . . . Under this system, the United States, with a population of less than 7 per cent. of the world's total, controls about 40 per cent. of the wealth of the world. One hundred years ago the average person had about 52 wants, of which 16 were regarded as necessities. To-day the wants number 484 on the average, of which 94 are looked upon as necessities.[3]

These facts, with their primary cause, are basic in enabling us to forecast the possibilities of improvement in the century that is ahead. They make it wellnigh certain that we shall increase in economic well-being in the future just as we have in the past in just the proportion in which we continue to apply science and engineering to our industries and thus produce more and more in goods and services per man hour, thus freeing more and more men, more and more time, and more and more brains for education, for research, for art and for all the other service industries. There is a saturation point for automobiles and radios, but there is no such thing as saturation in education or the service industries generally.

Civilization consists in the multiplication and refinement of human wants. It is a simple historical fact that these wants have actually developed with great rapidity wherever and whenever labor-saving machines have been rapidly introduced. In 1900 60 per cent. of our population was on, or supported immediately by, the farm; in 1930 not over

[2] "The Social Implications of Scientific Discovery." Published by the American Philosophical Society, Philadelphia, March 15, 1938.

[3] This last paragraph of the quotation from Compton he in turn takes from a pamphlet distributed by the First National Bank of Boston.

44 per cent.[4] Without serious unemployment in that period the millions of displaced farmers found their way into garages, service stations, newly created secretarial jobs, news reporting, a newly created telephone service, advertising, insurance, gardening, domestic service and a thousand other service industries, and no serious or prolonged unemployment occurred until the enterprisers who normally create the new jobs began to be suppressed, legislated against and scared by unwise financial and political policies. The faster science and engineering are applied to industry the faster we ought to progress. There is literally no other way of comparable effectiveness to raise the standard of living, and the chief element in its effectiveness is in getting more power into the hands of the laborer so that he can produce more for himself, for in the last analysis the laborer taken as a whole gets under almost any modern social system practically all that he produces. According to the United States Department of Commerce, in 1936 labor received directly 66.5 per cent. of the national income. Indirectly it received nearly all the rest of it, since the idle rich represent an insignificant fraction of the population and they pass on practically all that they receive to workers of some kind.

My forecast of the future, then, must depend on what the future's sources of power are to be and on the cost of that power. That is why I began with a consideration of the possibility of getting more work out of a pound of coal. At present the main sources of power are coal and oil, with water playing a minor role and being in general more expensive. This situation will continue for a thousand years, for though the oil will perhaps be gone in fifty years, the coal will last for at least another millennium. The big steam plant is now nearly or quite as efficient as the best Diesel motor, but for small power purposes, motor vehicles and the like, the internal combustion engine is and will continue to be indispensable. However, we already know how to make liquid fuel from coal, so that when the oil is gone we shall still be able to get liquid fuel for our internal combustion engines. There are, I think, no other possible sources of power of comparable cheapness. When the oil and the coal are gone we shall get our power either directly from the sun through solar motors, or wind mills or tidal machines, or else indirectly through growing and burning plants; but it will then cost us more than it does now. So far as tapping the energy "locked up in the atoms" is concerned, we can count that out. We can of course do it now in principle through radioactivity, but I see no possibility fifty years from now of ever supplying the world's power needs, or even a minute portion of them, from any such source.

For the foregoing reasons, then, fifty years from now the world will look to us, from the point of view of power, not so very different from what it looks now. Air travel will of course have increased, but the great bulk of the freight will go as now by surface vehicles or by steamships propelled in the essential particulars much as they are to-day. The art of communications, too, is already a pretty well perfected art, and though it may be considerably cheaper than now, more messages being simultaneously carried over a given cable, so far as the techniques used are concerned I do not expect any very radical or startling change.

Among the natural sciences biology has the opportunity to do the big new things so far as their immediate effect on human living is concerned, and I have no doubt that in the field of public health the control of disease, the cessation

[4] These figures are taken from the U. S. Census, which classifies as belonging to the "rural population" all persons living in the country or in cities, towns and villages of less than 2,500 inhabitants.

UNIVERSITY OF MICHIGAN LIBRARIES

of the continuous reproduction of the unfit, etc., big advances will be made, but here I am not a competent witness, and I find on the whole those who are the most competent and informed the most conservative.

The most burning and most uncertain situation about the future has to do with social and political matters, and it should be remembered that all the foregoing forecast was based on the assumption that our present civilization would not be destroyed by man's present or prospective international wickedness, stupidity and folly. I know of no direct way in which science can prevent that, for I see no prospect of our ever being able to turn some new type of ray upon a dictator filled with the lust of power and conquest and thus transform him into a humanitarian. Indirectly, however, the sciences of explosives and poison gases, of aerodynamics, of communications with its corollary, the rapid spread of *knowledge* among the people, are doing the work. It was the fear of the bombing of London and Paris that prevented the beginning of another world war last September. The peoples of all countries, including the dictatorships, are coming more and more to the realization that such another war can bring only death and destruction to everybody—the end of civilization, not the world domination which the demagogic leader promises. It is the rapid spread of knowledge by the effective methods that modern science has developed that gives good ground for hope that a world war will not come. The science of geology has shown that something like three fourths of the coal and the metals, the ultimate sources of power, are in the democratic countries. This fact together with the knowledge that these countries can be and have already been roused to arm to defend themselves is the great influence that makes for continued peace in the world to-day and that gives promise that a permanent method of assuring peace may ultimately be worked out. But these countries must have the intelligence, the long-range selfishness to see the hopelessness, the folly at a time like this of a policy of division and isolation. They must obviously, it seems to me, *join their powers* in time to show the international bandits the hopelessness of their threatened spring at the throat of the world. If they, including ourselves, will do this, then I think there will be no war, and then I stand by my prognosis of a golden age ahead through the further growth of science and its application to the well-being of mankind.

SEA FLOORS OF GLACIER NATIONAL PARK[1]

By Dr. CARROLL LANE FENTON

WASHINGTON, D. C.

NEAR the northwestern corner of Montana lie what Meriwether Lewis called the "shining mountains." Peaks of buff, red and green rise in two ranges; blue lakes extend from the plains into valleys walled by many-hued rocks. Yellow flowers grow at the edges of snowdrifts, while in high, snow-swept basins the ice of sixty glaciers gleams. They, and much greater ice streams of the past, give their name to Glacier National Park.

The region has contrasts as well as color. Meadows surround vast rock-heaps; canyons alternate with cliffs. In the valleys are tall Douglas firs and cedars, while passes support stunted pines and willows whose catkins stand barely two inches above the ground. Along the eastern border of the Park, mountains rise abruptly from plains, and old rocks stand on top of young ones. Those old rocks form every high ridge and peak—yet their beds contain beaches and sea bottoms, and show how storms swept muddy shallows, 650,000,000 years ago.

A topsy-turvy, paradoxical jumble? It seems so to many a tourist who tries to grasp it as he travels by bus or heavy-footed cayuse. It is less confusing to those who walk, for they have time to look, to think and to piece misplaced sections together. In the end, hikers have a story which "makes sense," even though it does mingle upheavals with such everyday affairs as wind and sandstorms blown from dry hills.

This story begins in the late Proterozoic Era, some 650,000,000 years ago. North America existed in these days, of course, but it was not like the continent across which we travel to-day. It probably was bigger and warmer. It also supported at least two seas. One of these spread northward across Arizona, at least as far as Wyoming. The other advanced from the Arctic Ocean. In time, it probably joined waters with the sea whose shoals and muds now lie far down in the Grand Canyon.

Rocks of the "shining mountains" were formed in the sea that came from the Arctic Ocean. That sea was long, narrow and shallow; the part of it which we know best was never very far from land. Rivers flowed from that land, bringing loads of sand and silt, as well as dissolved minerals such as dolomite and lime. For millions of years these sediments gathered, while the sea bottom intermittently sank. At last it held a varied series of rocks whose full thickness is 60,000 feet.

At this point there is a gap in the story; a gap which must be filled in from rock-records in other parts of Montana. They show that the Proterozoic Era ended with uplift which built mountains. The mountains then were worn away, the country began to sink, and new seas advanced from the Arctic. Though they never were very deep at one time, their basins sank repeatedly, and so allowed vast amounts of sand, silt and mud to settle in the basins. Where they can be found, these deposits tell events of the Paleozoic Era, which lasted 350,000,000 years.

This brings us to the Era of Reptiles, and back to the region of Glacier National Park. Sinking again gave way to uplift, and rocks that had lain beneath the sea were pushed upward into swampy land.

[1] A detailed statement of evidence on which conclusions in this article are based has been published in the *Bulletin of the Geological Society of America*, 48: 1873–1970, 1937.

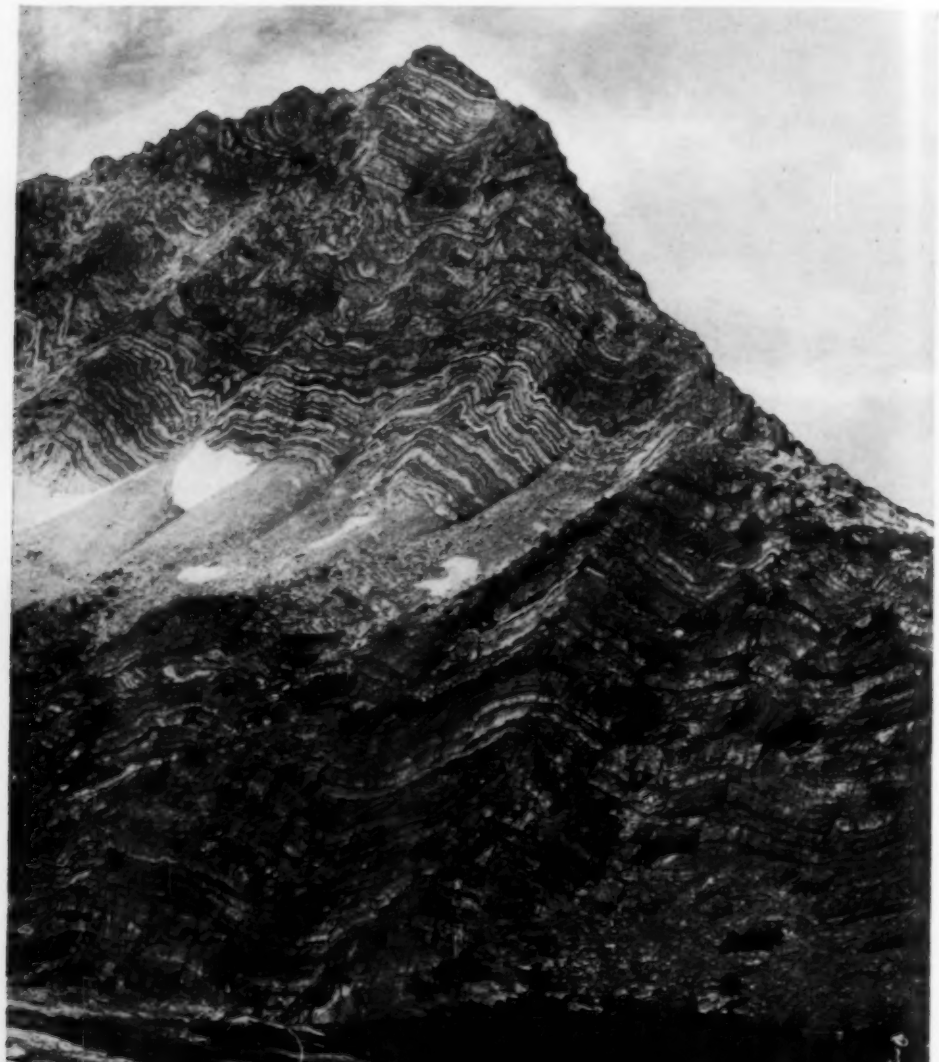


Photo by Hileman.

BEDS OF RED AND WHITE STONE

WHICH SETTLED IN A SHALLOW SEA MORE THAN 600,000,000 YEARS AGO. THEY WERE BENT, BROKEN AND PUSHED ACROSS ONE ANOTHER WHEN UPLIFT MADE THE MOUNTAINS OF GLACIER NATIONAL PARK.

(C) *Photo by Hileman.*

HARDENED, RAISED SEA BOTTOMS

FORM SCENERY IN THE "SHINING MOUNTAINS." HERE, GRINNELL GLACIER IS DIGGING THE MARINE ROCKS AWAY ALONG THE CONTINENTAL DIVIDE.

In those swamps appeared dinosaurs with short forelegs and ducklike beaks, as well as others whose bodies were sheathed in armor. They wandered through glades which to-day are bare plains of the Blackfeet Reservation. Then they fled before a Cretaceous, or Chalk Age, sea whose muds now lie beneath the mountains as well as in ridges near them.

Soon—geologically soon—that sea itself began to retreat. A tremendous force, pushed from the westward, squeezed and bent the rocks that had settled in the basin through two long eras. Before this force, the strata heaved upward in folds; pushed still farther, they crumpled and broke, moving upward and eastward more than thirty miles. When the earthquakes of uplift ceased, mountains of Proterozoic rock stood upon beds of Cretaceous age stretching eastward to form the plains. Between them lay the Lewis Fault: the break along which the mountains moved, representing a gap in time of two geologic eras and about 600,000,000 years.

Though crumpled and shattered near the line of uplift, the mountain-forming rocks suffered slight change. Appearing much as when they were formed, they link the past with modern scenes of valley, peak and glacier; recording conditions with range from shifting winds to advances of sea, they reveal ancient environments in often surprising detail. Since fossils occur in many beds, their structures (coupled with sediments) show how very ancient life met environmental demands.

The scenic importance of rocks first impresses the visitor. He sees mountains whose colors are more varied than those of the Grand Canyon—each color the product of special events in which land, streams and sea combined. He finds that low limestones make waterfalls, while

UNIVERSITY OF MICHIGAN LIBRARIES

RIPPLE MARKS

MADE BY CURRENTS WHICH SWEPT ACROSS A SHALLOW BAY WHEN WESTERN MONTANA WAS A SEA. SUCH MARKS ARE STEEPER ON ONE SIDE THAN ON THE OTHER.

RECORDS OF SHIFTING WINDS

THESE WAVE-MADE RIPPLES ARE EQUALLY STEEP ON BOTH SIDES. WHEN THE WIND CHANGED, WAVES BUILT NEW RIPPLES ACROSS OLD ONES.

CROSS-BEDDED QUARTZITE
THIS SANDY STONE CONTAINS PEBBLES WASHED INTO SHOALS BY STORMS.

high ones form steep cliffs. Red argillites produce pinnacles and ridges; greenish ones underlie gentle slopes or appear in low, rounded peaks. Thus varied Proterozoic muds have controlled mountain sculpture by frost and streams, as well as the work of glaciers that spread during the last Ice Age.

Those who seek ancient environments are concerned with smaller features than these. Formations furnish a general scheme, but the countless strata and layers of which they are built hold those detailed records of change which tell how deep the ancient sea was and how salty. They trace its shiftings, its currents and its waves. Some even tell how fast sediment settled on its bottom.

Let us start with the rate of sedimentation. Some beds of rock are thick and are made of coarse pebbles and sand; they show rapid accumulation near the mouths of heavily laden streams. Other beds are fine mudstones or lime in layers almost paper-thin. Some strata of green argillite (a shale-like stone) show 56 distinct layers to the inch. If each layer is a summer's or a winter's mud, that inch took 28 years to form.

But is each layer a season's deposit? That question is answered by finely banded marble which lies below the argillite. Bands in this marble are dark and light, the dark ones being made by carbon which came from simple water plants. Such plants grow abundantly in summer, when light is strong; they grow slowly or not at all in the winter, when sunlight is scanty. The evidence becomes specially convincing when we trace carbon-rich layers of stone directly into colonies of fossil plants, and find that these layers not only are dark, but are much thicker than layers which have very little carbon.

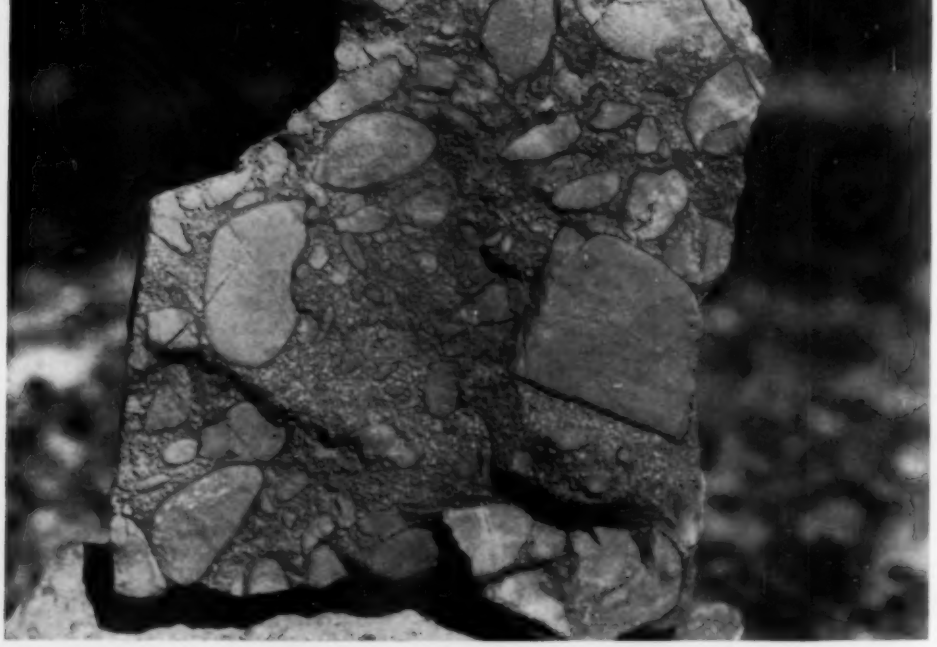
With a little practise, this method can be extended to beds in which carbon is scarce. It also can be used to interpret layers so thin that their rate of accumula-

tion was almost unbelievably slow. In one series of mudstones which appear high in the mountains, many layers accumulated at a rate of 60 to 75 years per inch, while some show the almost unbelievably slow rate of 340 years for a single inch of stone.

These beds mean quiet as well as shallow water—yet such conditions were not the rule. Beds of limestone, shale and sand unite in bearing ripple marks that were made when breezes swept the shoals in which they were deposited. When the wind changed it built new marks cutting those already formed; sandy beds near Swiftcurrent Pass abound in cross ripples so perfectly shaped that their crests enclose almost exact squares. Breezes were uncertain indeed on that special Proterozoic bay.

Currents also swept near shore, building ripple marks with one side steep, not symmetrical like those of waves. They often are found with criss-crossed layers of alternating mudstone and sand. Such cross-bedding is one mark of shoals across which conflicting currents swept, breaking the sediments beneath and dropping the fragments at varied angles. It often appears in river channel deposits and dunes, but no clear trace of either has been found within Glacier National Park.

But what are these dark red lumps scattered among beds of white sand? They seem to have rolled, snowball style, over a surface of sticky mud. Storms set them on this path to growth; reaching shallows, they stranded in sand when the waves or currents became too weak to carry them farther. The balls settled among a mixture of sand, pebbles and chips of partly-hardened mud which were torn from the sea bottom while the mud balls were rolling about.

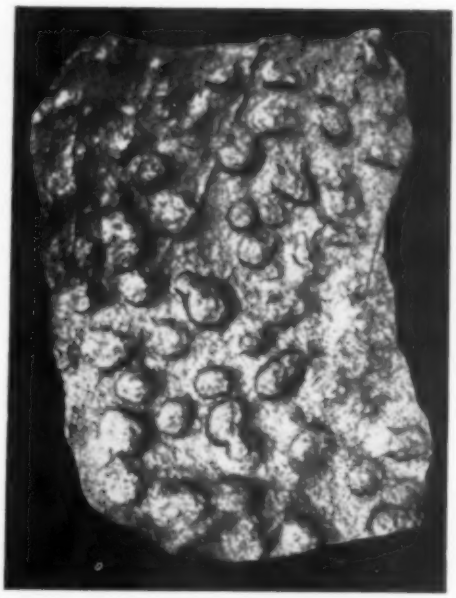


MUD BRECCIA

THE LARGE PEBBLES ARE MUD WHICH STORMS TORE FROM THE SEA BOTTOM AND MIXED WITH COARSE SAND FROM THE LAND.

Those storms did not advance into shoals from the open sea. Instead, they apparently began on land at the end of each dry, or summer, season. Break of the drought was heralded by gales which carried sand and pebbles seaward from the semi-desert hills. Then cloudbursts revived dry streams, turning them into floods that carried vast quantities of sediment to the wide-spread shallows near shore. There they took up layers that had partly hardened, rolled sticky mud into balls, mixed fragments of all sorts together, and then allowed them to settle in strata whose technical name is *mud* or *edgewise breccias*.

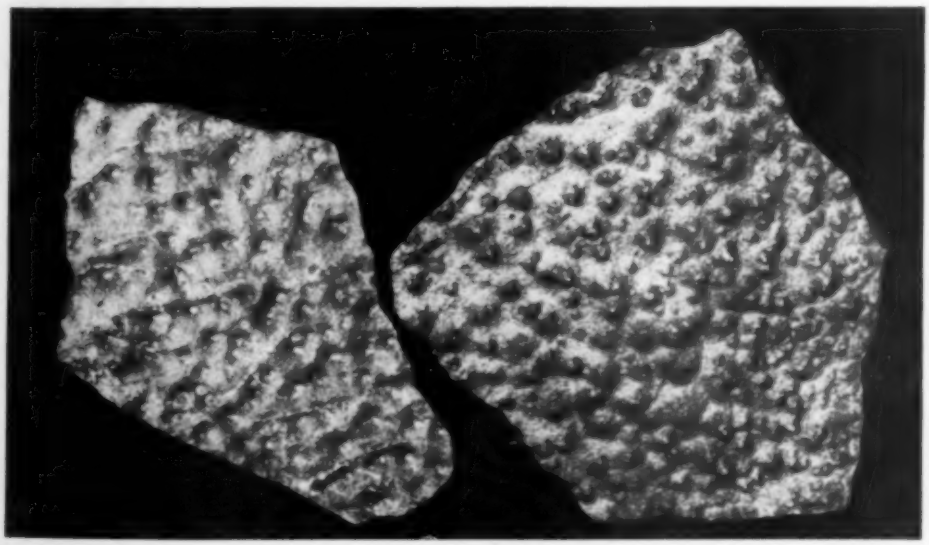
These breccias mean that water was shallow: much shallower than that of most lakes. Over thousands of square miles and through millions of years, the Proterozoic sea bottom lay so near the surface that each dry season laid it bare. Then sand flats or mud flats steamed in the sun, to be pelted and pitted by rains that fell before they had time to harden. Hail dug even sharper pits, whose oblique angles trace directions of wind through which the hail-stones fell. Often a single sandy ledge records storms of both land and sea in its cross-beds, mud balls, pebbles and rain or hail pits.



RAIN PRINTS

ALMOST 650,000,000 YEARS OLD. THEY WERE MADE IN PLASTIC, BLUE-GREEN MUD.

It also may show that the muds dried and cracked, as pond muds do to-day. Unlike pond muds, the edges of cracked



SLEET PRINTS AND FILLINGS

ON THE LEFT ARE PRINTS MADE BY SLEET, DRIVEN BY A SOUTHWEST WIND. ON THE RIGHT IS A PIECE OF HARDENED MUD WHICH COVERED AND FILLED THE SLEET PRINTS.

CRACKED MUDS

OF A SEA SO SHALLOW THAT THOUSANDS OF SQUARE MILES LAY BARE, DURING EACH DRY SEASON. THE LARGE SLAB SHOWS THE UPPER SIDE OF A BED; THE SMALL ONE, THE UNDER SIDE. NOTE HOW THE CRACKED EDGES TURN DOWNWARD.

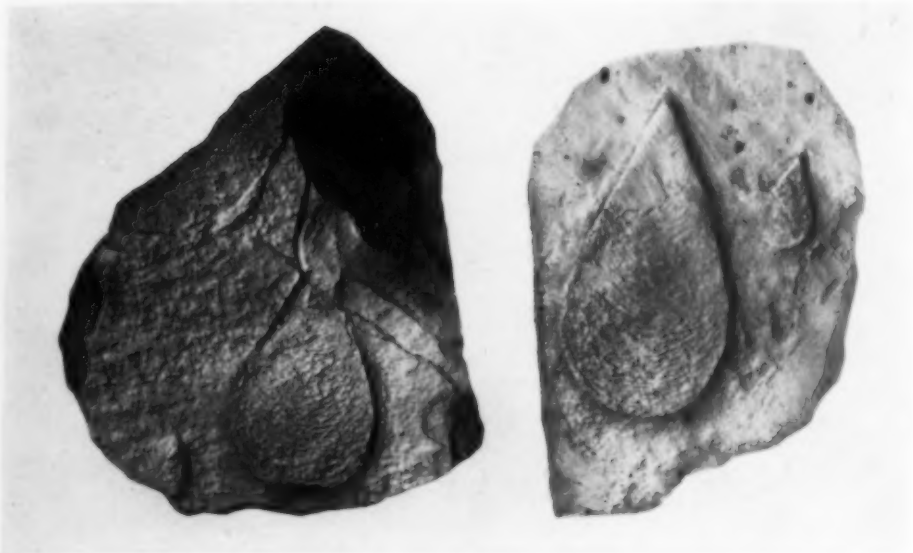
Proterozoic muds turned down or refused to curl—a situation reproduced to-day if we dissolve salt in fresh water silts. The more salt we add, the more the edges curl downward as water in our test pan evaporates: a clue to shifting salinity in seas whose sediments are variably cracked.

But must the rocks of Glacier Park be marine? There are two theories which hold they are not. One of these theories pictures these strata as deposits in a chain of inland lakes, thus accounting for their seeming lack of fossil marine animals. The other theory compares the rippled, mud-cracked beds to those left when streams overflow and cover adjoining plains with silt. It would make at least three fourths of these rocks the products of such seasonal floods.

The latter explanation is hard to believe. Though streams contain very little salt, saline mudcracks are the rule in strata of Glacier Park. Many strata also contain sandy cubes which are casts of salt crystals formed when shallow waters evaporated. Yet these very beds are supposed to be silts left by overflowing streams!

But why not a great salt lake? It would have to be very great indeed, for the basin filled by these sediments would have held twenty lakes the size of Superior. Though shifting, it sank through millions of years while 60,000 feet of rock were carried down from its shores. Only seas are known to last so long; and as seas we may regard the waters that swept Montana in Proterozoic times.

With this the story of fossils agrees. For animals it is incomplete: two slabs bearing burrows of worms that bored in a beach of fine, brown sand, and two marks that seem to be clam trails. Supposed crustaceans prove to be broken



MARINE LAMP-SHELLS

OR BRACHIOPODS. FOUND NEAR THE BIG BELT MOUNTAINS OF MONTANA, IN ROCKS EQUIVALENT TO THOSE IN THE WALL OF ICEBERG LAKE CIRQUE.

Photo by Hileman.

CIRQUE WALL OF ICEBERG LAKE

CUT BY AN ALMOST VANISHED GLACIER. THE LIGHT GRAY BAND IS A BANK OF FOSSIL ALGAE, ABOUT 100 FEET THICK.

CONE-SHAPED ALGAE

OF THE SORT THAT BUILT THE BANK ABOVE ICEBERG LAKE AND THE REEF SHOWN IN THE FOLLOWING PICTURE.

fronds of brown seaweeds; eleven shells from the Big Belt Mountains undoubtedly are marine. Although these shells were found 150 miles from Glacier Park, they lay in rocks whose age was identical with the "limestones" (really dolomites) which form much of the Continental Divide in the Park and northward into Alberta. These are the rocks whose supposed lack of sea animals was turned into evidence that the "limestones" settled in freshwater lakes.

Though animal remains are few, fossil plants of the group called algae are common. At the very foot of the mountains they appear in gray marbles that weather to brilliant buff. When broken, some strata show irregular films of black—the supposed crustacean shells. Those films actually are remains of seaweeds which looked somewhat like the modern rockweed, but grew on muddy banks. If abundance as fossils means abundance in life, those seaweeds were common and wide-spread.

A few feet higher lie massive beds of closely packed, oblique columns. Each column is oval in section, consisting of hundreds of convex layers resembling saucers piled bottom-side-up. Though opinion is not unanimous, it seems certain that these columns were built by colonies of filamentous algae, each of which deposited layers of lime in the jellylike mass surrounding its fibers. Thus, even while alive, these plants built rocks which were firmer than the muds that settled in less populous bays.

The thick green and red formations have not afforded one fossil plant. But scarcely did lime bottoms return when a new sort of alga appeared, spreading out in biscuits or domes, or crowding into compact beds which are as black as coal. Though now largely dolomite, the algal filaments provided carbon enough to stain

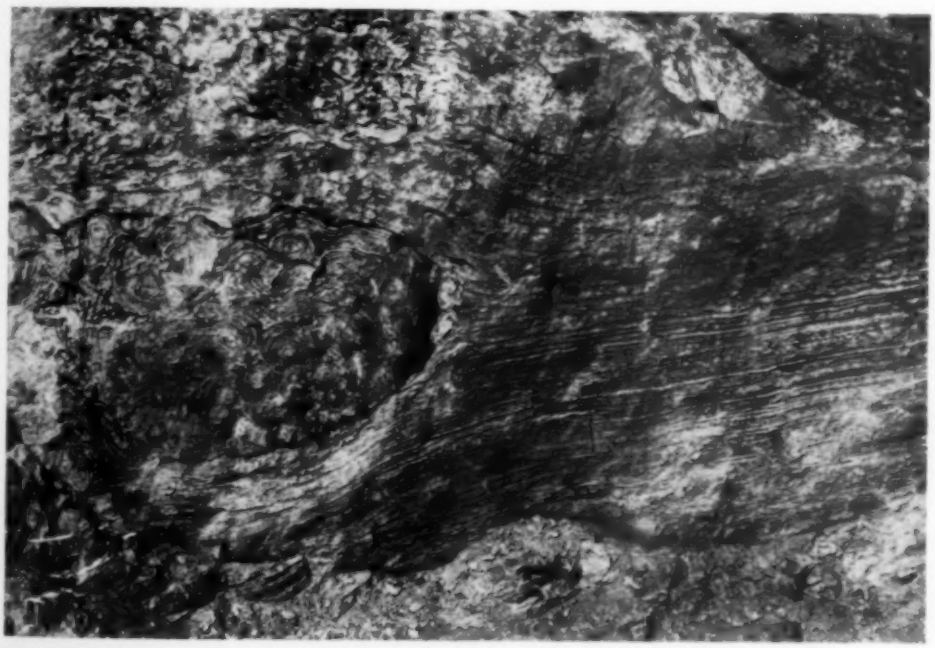
that rock black and to color the adjoining beds.

Scattered widely through Glacier Park and in southern Alberta as well, these fossils are most abundant on two of the southern passes. There they lie among dwarf willows and snow, above slopes where strange alpine plants sink roots two feet into the soil as anchors for three-inch crowns of leaves. Again one contrasts the alpine present with a past of seas and primitive plants whose life processes built layers of stone.

Still higher are ledges about a hundred feet thick, formed by conical colonies. On exposed spots they expand into sheets —apparent proof that two "species" are one and that early algae varied in form according to varied conditions of life. As a matter of fact, several true species of algae probably combined in each of these ancient colonies, just as they do in modern growths. One group of species made the columnar fossils, another produced the black masses, and still a third made the cone-shaped colonies which form the massive gray ledges that show plainly in the buff cliffs of almost every high mountain in the Park.

Some geologists call such massive beds reefs, though a reef should be a dome or ridge. For decades no true reefs were known from Proterozoic rocks in the northern Rockies. Now, trails pass several small ones, while a trans-mountain highway has cut two whose perfection fits them for text-books. They show the low central core, or ridge, composed of conical colonies whose weight squeezed and compressed the soft muds on which they grew. These squeezed, depressed layers prove that reefs can develop on soft bottoms as well as the hard platforms which are furnished by stony banks or submerged volcanoes.

These reefs also show how greatly the plant colonies indulged in ecologic variation. Where crowded, they formed compact cones; at the reef edge, where currents swept, they spread out in wrinkled



A REEF OF LIMY ALGAE

WHICH GREW ON MUD SO SOFT THAT THE WEIGHT OF THE REEF BENT IT DOWNWARD. GOING-TO-THE-SUN HIGHWAY, 6.4 MILES NORTHWESTWARD FROM LOGAN PASS.

SUBMARINE LAVA

PART OF A FLOW WHICH COVERED LIVING ALGAE AND BAKED THEM INTO REDDISH BROWN LUMPS.

sheets. Where crowding was not intense, they assumed spongelike forms, while out on the open, uncrowded mud they grew in irregular, flattish masses. An associated "species" grew in closely packed columns, while another (which grew away from the reefs) formed flattened biscuits of stone whose widths reached 5 feet. Where water was very shallow and waves secured a great deal of air, these biscuits fused into compound colonies 8.5 feet in diameter and 3 to 4.5 feet thick.

Though these colonies varied according to different surroundings, they met no such problems as those that faced plants which are found in greenish shales near the crest of the Continental Divide. These algae lived on shallow, wave-swept shoals on layers of hardened, deeply cracked mud that a few months before had been land. Currents and storms swept these shoals, overturning small colonies and piling layers of mud upon others that were too massive to be disturbed. At times the sea water disappeared, allowing both plants and mud to dry out; at others, submarine lavas poured forth, baking the algal colonies to brittle balls that now are covered by lumps and ropy twists of lava. Between eruptions the plants returned, only to meet a similar fate when new cracks opened and more lava emerged. They could find no peace in a steaming sea which dried or was flooded between eruptions. Even when lava no longer poured out, these algae failed to regain foothold in the bays. Though they may not at once have become extinct, they vanished from the records of Glacier Park.

The import of those records is clear. They link the present with the past—not merely in scenery, but in waves, winds, rivers, sea floors and even submarine eruptions. They present early environments with detail not achieved for many later seas, whose deposits are much more familiar. Finally, they show simple organisms living as simple things live today, meeting failure or success as conditions and their own abilities decide.

SPANISH METHODS OF CONQUEST AND COLONIZATION IN YUCATAN, 1527–1550

I. ROYAL POLICY

By Dr. ROBERT S. CHAMBERLAIN

THE CARNEGIE INSTITUTION OF WASHINGTON

PORTUGAL and Spain were the leaders in the great movement which has been termed the Expansion of Europe. They were the first of the states to create colonial empires in the modern sense, the former laying the foundations for overseas expansion in the mid-fifteenth century as a result of the activities of Prince Henry the Navigator, and the latter through the discovery of the New World by Columbus at the close of the century. The empire of Portugal was, with the exception of Brazil, wholly maritime and commercial, consisting of islands and trading stations along the sea lanes around Africa to India, the Spice Islands and China; that of Spain was continental. With her slender resources, Portugal held her possessions but thinly and soon lost her importance; Spain, with her greater population and wealth, from the first directed her efforts toward true colonization and, in an almost incredible display of spiritual and material force, created one of the greatest overseas empires which history has witnessed while simultaneously engaged in establishing her hegemony in Europe.

Being first in the field, in establishing their overseas empires and therein creating something which had hitherto not existed, Portugal and Spain were forced to rely entirely on their own native talents. They could look to no other peoples for guidance, and they could not rest their policies on the experience of any others.

The Spanish lands of the New World pertained directly to the Crown of Castile, and it was consequently the sovereigns of Castile who were required to meet the extremely complex problems arising from the creation of a vast colonial empire in lands heavily populated by unknown peoples, certain of whom possessed ancient and relatively high cultures. All activity toward colonization derived from the Crown as the sole source of authority and the proprietor of the lands concerned. In this connection it is to be noted that among the Spanish kingdoms it was Aragon, through her Mediterranean holdings, and not Castile, which had gained experience in the administration of overseas possessions. The sovereigns of Castile to the very year of the discovery of the New World had been engaged in the *Reconquista,* consummated by the conquest of Granada, and had been concerned with the consolidation of their realms and the establishment of their supreme authority. Castile heretofore had not turned her attention outward, and in solving the problems of overseas colonization she was forced to build from the ground up.

The efforts of the Spaniards in the field of colonization have all too frequently been lightly dismissed, especially by Anglo-Saxons, as those of a people who possessed no aptitude for such endeavor and who had no objectives other than to wring from the natives, the mines and the soil the last ounce of personal profit. The early colonists have been represented as little more than bands of utterly cruel and rapacious, if indeed amazingly daring and courageous, conquerors, who killed, robbed and oppressed for no other purpose than to achieve sudden wealth in its most tangible form, that of gold. The

policies of the Crown have been regarded as those of thoroughly unenlightened, intolerant, oppressive, despotic and heavy-handed absolute monarchs who, disregarding completely the welfare of colonists and Indians alike, sought nothing more than the full exploitation of the overseas possessions in their own benefit and in that of the metropolis.

On the opposite extreme are those of a so-called revisionist school, who in comparatively recent years have presented a wholly favorable picture of a beneficent government which brought to the Indians the blessings of a higher civilization and a true religion. Unfavorable aspects of government, conquest, colonization and the Church have been glossed over, rationalized or explained away, and the frequent wide divergence between the theories, policies and intent of the Crown on the one hand and the actual practices and conditions on the other has been ignored, as has the Spanish tendency toward legalism and formalism, which at times engenders strict observance of the letter and form, but violation of the spirit and intent.

Both contentions have bases in actuality, and, as is almost invariably the case, the truth lies at some undetermined point between the two extremes. It is my purpose briefly to analyze, compare and contrast various aspects of the policies of the Crown on the one hand and on the other the actual practices as exemplified in

Drawn by Edwin M. Shook.

A MAP OF THE MAYA AREA, 1527–1550

CHICHEN ITZÁ AND SURROUNDING COUNTRY, LOOKING EAST

The principal structures in the background are, from left to right, the Ball Court, the *Castillo* and the Temple of the Warriors. The group in the foreground to the left consists of the *Casa del Venado*, the *Casa Colorado*, the *Casa de Monjas*, the *Caracol* and the *Akab 'Dzib*. Between the lines of the former and latter groups of structures is the *Osario*. To the right in the foreground is the *hacienda*, now headquarters of the Carnegie Institution of Washington, and the chapel. It was among, or close to, these buildings, already abandoned by the Maya, that the Castilians, late in 1532 or early in 1533, established the short-lived city of Ciudad Real. According to the most recent reconstruction, the history of Chichen Itzá is briefly as follows. Founded at an uncertain date, Chichen Itzá was occupied by Yucatecan Maya until A.D. 889. This is the period of pre-Mexican architecture. There followed, from 889 to 987, an era of inactivity. From 987 to 1185 the Itzás, a Mexican people under the semi-legendary Quetzalcoatl, or Kukulcan, as he was known to the Maya, occupied the city. A period of great architectural activity ensued, in which new forms, based on the worship of Quetzalcoatl, the Feathered Serpent, were introduced. Kukulcan founded Mayapan as a political capital, and a league of the three foremost cities of Yucatan, Mayapan, Chichen Itzá and Uxmal, known as the League of Mayapan, was formed. Chichen Itzá remained an important religious center. The league, under the dominance of Mayapan, remained supreme in Yucatan until the mid fifteenth century, when internecine strife led to its break-up, the destruction of Mayapan and the abandonment of Chichen Itzá. Yucatan thereupon fell apart into relatively small independent *cacicazgos* and a period of political decadence followed. There was, however, something of a revival of Maya influences in the crafts.

the conquest and initial colonization of Yucatan.

In approaching the subject of the methods of conquest and colonization two factors must be borne in mind, as has just been inferred: first, the policies and intent of the sovereigns of Castile, which are well set forth in the "Recopilación de Leyes . . . de las Indias," published in 1680, one of the greatest of colonial codes, and, second, the acts and purposes of those who carried Castilian dominion to the Americas. Conquest and colonization were given their character by the interworkings of these two factors, and the latter often negated the former, at least temporarily. The soyereigns through laws and ordinances established the norms within which, exercising considerable initiative with respect to methods and specific policies, the *conquistadores* reduced and settled the lands over which they were delegated authority. In this regard, it is to be pointed out that the full forms of absolute royal government were not established until after the great conquests had been achieved and initial colonization had been begun.

The Crown had as its objectives the expansion of its realms, the gaining of

THE *CASTILLO*, CHICHEN ITZÁ

This view shows the structure as it appeared during the visits made to Yucatan by the American diplomat and explorer, John L. Stephens, in 1839–1840 and 1841–1842. The drawing was made by Frederick Catherwood, an English artist and architect who accompanied Stephens. The *Castillo* was dedicated to the worship of Kukulcan, or Quetzalcoatl, the patron deity of Chichen Itzá.

further subjects, the increase of revenues and the Christianization of the Indians and the winning of them for the Roman Faith. The *conquistadores* and other early colonists were motivated by many and varied forces: desire for opportunity denied to them in Castile, the wish for personal wealth and position quickly and readily achieved, desire for glory and love of adventure, the desire to serve their sovereign and add to the luster of his throne, the crusading spirit and, to a certain degree, in instances, a sincere desire to aid in the winning of souls for the True Faith.

The principal problems before the Crown were the establishment of government, economic institutions, the Church and social forms, the latter of which, resting on religious bases, were centered in the relations between the natives and the Castilians and the legal status to be given to the Indians. The political and economic problems with which the sovereigns of Castile were confronted were in the broader sense common to all colonizing states, but the religious element assumed a vital importance with respect to Castilian colonization which it possessed nowhere else.

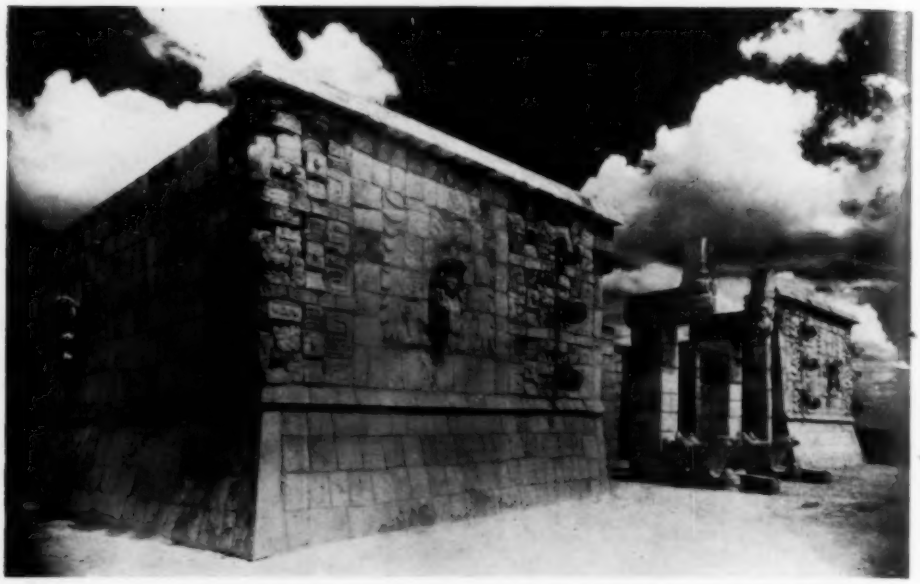
The sincere religious zeal of the Crown can scarcely be overemphasized, and it is to be remembered that the crusading spirit was strong in Spain after the centuries of the *Reconquista,* which, significantly, is also known as the Perpetual Crusade, and that upon the conquest of Granada this spirit was projected outward. Closely related to this religious zeal was the equally sincere desire of the Crown for the well-being of its Indian vassals. The Christianization

of the natives, their entrance into the fold of the Church and their welfare was invariably declared by the sovereigns to be "our principal desire and intent," and there is no reason to doubt this declaration as a sincere statement of purpose. To gain an appreciation of the importance of the religious motive it is only necessary to recall the aims of Isabella, the policies of Charles V, who, with all his vast political responsibilities as Emperor and King of Castile and Aragon, never lost sight of his objectives of reforming the Church and of healing the breach between Catholics and Protestants and bringing the latter once more within the fold of Rome, and the purposes of Philip II, who, however intolerant, regarded himself as a chosen instrument of God to restore the unity of Christendom within the Church, extirpating what he believed to be the false doctrines which were rending the seamless robe of Christ.

The conquest and colonization of the New World consequently has two aspects, the temporal and the spiritual. The subjugation of the natives by force of arms or by peaceful means, the settlement of conquered lands and the establishment of governmental and economic forms on the one hand and the establishment of the Church and the effort to win the Indians to Christianity and the Church on the other, everywhere proceeded simultaneously.

It should be emphasized, furthermore, that the Crown considered its claims to dominion over the New World to be juridically above question, as the lands and peoples of the Americas had been given into the power of the sovereigns of Castile by the Pope. In accord with this theory it was not only the right of the Castilian monarchs to bring the New World under their control, but their obligation, and in so doing they regarded

THE RESTORED *CASTILLO*, CHICHEN ITZÁ, VIEWED FROM THE NORTH
The temple, eight meters in height, was built on the great pyramid, sixty meters square at the base and twenty-four meters high. Great structures of this kind erected by the Maya served as places of worship, as government buildings and as dwellings for the rulers, priests and nobles. The restoration of the *Castillo* was carried out by the Mexican Government.



NORTHWESTERN FAÇADE, TEMPLE OF THE WARRIORS, CHICHEN ITZÁ
Showing the intricate stone work and skilled carving of the Maya buildings. The stones, set into mortar and rubble, form a veneer. At the corners and on the walls are elaborate masks and shields, and in the doorway are serpent columns, symbolic of Kukulcan, the Feathered Serpent.

themselves as bound to conform with the principles of divine and natural law and justice, thus to maintain just title. The natives of the Indies were already their vassals, and were obligated to acknowledge their dominion, and in establishing effective control they were making actual a condition which already existed in theory. Natives who did not immediately accept their dominion were consequently "in rebellion" against their rightful lords.

The broader policies of the Crown with respect to the conquest and colonization of the Indies are indicated in the *capitulación*, or patent, by which Charles V, on December 8, 1526, assigned to Francisco de Montejo authority to reduce and settle the "Islands of Yucatan and Cozumel," with the titles and offices of *Adelantado*, Governor and Captain General, the first hereditary and the latter two for life. These offices conferred upon Montejo superior political, judicial and military authority within the lands concerned as a representative of the sovereign. Montejo was to conquer and colonize Yucatan at his own cost, and was to receive in hereditary grant four per cent. of the revenues originating within the province from whatever source. An area ten leagues square within the province was assigned to the *Adelantado* to be held in perpetuity. At least two towns, each of a minimum of one hundred citizens, were to be founded, and two fortresses were to be constructed. To foster colonization the settlers were to be assigned lands, and they were granted temporary reductions of and exemptions from certain taxes and duties. Portions of stipulated royal revenues were to be assigned to the construction of public works and hospitals and for the maintenance of clergy and churches until the Church was formally established in the province. License to enslave natives who refused to accept Castilian dominion and Christianity after being

PATIO, THE *MERCADO*, CHICHEN ITZÁ
The *Mercado* is one of the structures which form the southwestern side of the Group of the Thousand Columns.

duly "required" was given. No persons excluded by law, such as hereties and converted Jews (*conversos*) and Moors (*moriscos*), were to be taken to the Indies.

General ordinances promulgated by the sovereign on November 17, 1526, to regulate captains and officials in the conduct of conquest and colonization and to protect the Indians and advance their welfare and Christianization were written into the *capitulación*. These ordinances provided that the natives should be treated as free vassals of the Crown, that the legal *requerimiento*, or "requirement," that they accept Castilian dominion and Christianity should be duly notified to them through interpreters and that war should be made only in self-defence and against natives who rejected the "requirement" and offered resistance, that only such natives as offered resistance could legally be enslaved, that the natives should not against their will be forced to labor for private persons and that those who voluntarily agreed to work should be duly paid, that the property of the Indians be respected and that trade be conducted justly, and that the natives should be indoctrinated in the Faith, protected, treated well and raised to a higher level of culture. Each expedition of discovery, conquest and trade was to include two qualified members of the secular or regular clergy. These clergy were charged with the task of converting and protecting the Indians, and war, enslavement and the partition of natives in *repartimiento* and their assignment in *encomienda* were to be carried out only with their counsel and consent. They were to report the entire course of conquest and colonization to the Council of the Indies and were to make known to that body all infractions of law and mistreatment of and injustices to the natives, that proper action might be taken. They were also to provide a good example to both colonists and Indians. The *Audi-*

THE TEMPLE OF THE WARRIORS, CHICHEN ITZÁ

This temple was erected during the period of Mexican influence, and is an excellent example of the late architecture of that era. The colonnade in front of the pyramid is projected a considerable distance to the right, and this extension and the colonnade at the side of the pyramid form the northwestern and northeastern sides of the great court known as the Group of the Thousand Columns. Other structures extend along the other two sides. The excavation and reconstruction were carried out by the Carnegie Institution of Washington.

encia of Santo Domingo also was to report to the Council of the Indies all cases of injustice toward the natives, with recommendation of punishment. Captains and officials who acted contrary to the more important provisions of the ordinances were to be deprived of office and property.

In this document the sovereign proclaimed his motives in the following words:

. . . it is Our principal intent and desire to draw the said Indians to true knowledge of God Our Lord and of His Holy Faith through its preaching and through the example of properly endowed [clergy] . . . in rendering them good

THE *CASA DE MONJAS*, CHICHEN ITZÁ

The *Casa de Monjas*, one of the most massive of the buildings of Chichen Itzá, is an example of construction at various levels. Usually Maya structures were placed upon truncated pyramids. This structure was erected in the pre-Mexican period, and consequently is Maya architecturally.

works and according them good treatment . . . , without offering them violence, oppression, harm, or ill in any manner, either in person or property. . . .

To prepare for what follows, it is perhaps necessary to summarize the course of the conquest of Yucatan. The conquest, which was begun in 1527 and was concluded by 1545, can be divided into three phases. The first is that from the autumn of 1527 to 1529, during which the *Adelantado*, having organized a relatively large and well-equipped expedition at Seville, established himself on the east coast and sought to reduce and colonize the peninsula from that quarter. Losses through disease and warfare and the realization that a comparatively large force would be required caused him to proceed to New Spain to secure further men and organize a new expedition. While in New Spain, Montejo altered his plans, and securing appointment as *alcalde mayor* of Tabasco, he established that province as a rear base for the conquest of Yucatan, recalling his forces from the east coast. With these developments the second phase of the conquest began, a phase which lasted from 1529 to 1534 or 1535. Completing the pacification of Tabasco, Montejo passed to Campeche, where he founded a town which was to serve as a center for the reduction of the peninsula proper. This phase ended in complete failure as a result of a combination of factors, the most important of which were the stubborn resistance of the Maya of the eastern, central and southern provinces and dissatisfaction among the soldier-colonists with the lack of gold, silver and other wealth. Discontent was brought to a climax by news of the conquest of Peru and its incredible riches, which, at a time when

THE *CARACOL*, CHICHEN ITZA

The *Caracol*, one of the most outstanding examples of circular construction in the New World, was built in stages, and includes both Mayan and Mexican elements. The circular aspects of the structure are Mexican, and may have been erected shortly after the Mexican invasion. The structure was restored by the Carnegie Institution of Washington.

the colony had at length been firmly grounded from the military point of view, caused large numbers of men to desert the province in the desire to reach more promising fields. With a steadily decreasing number of soldier-colonists, and faced by large numbers of hostile, or potentially hostile Indians, the *Adelantado*, despite his efforts to make it possible to remain, was forced to abandon the region. Yucatan could have been permanently settled at this time had the men who composed the forces of the *Adelantado* been of a truly colonizing type.

THE BALL COURT, CHICHEN ITZÁ

Ball courts are found throughout Middle America, that of Chichen Itzá being perhaps the largest and most impressive. In these courts *pok-ta-pok* was played, a game in which the players sought to cause a rubber ball to pass through stone rings high on the two parallel walls of the court, midway between the ends. The players struck the ball, which was sometimes as much as a foot in diameter, with their hips and knees, but were not permitted to employ their hands and feet.

Upon abandoning Yucatan the *Adelantado* passed to Mexico, placing his natural son Francisco in the government of Tabasco. Appointed governor of Honduras-Higueras by the Crown and assuming this office in 1537, he was until 1544 engaged in the pacification and administration of that province, of which he is the true conqueror, and in the government of Chiapas, and he did not return to Yucatan until the close of 1546. The final phase of the conquest of Yucatan, extending from about 1540 to 1545, was carried to a successful conclusion under authority of the *Adelantado* by Francisco de Montejo the Younger, Francisco de Montejo, the nephew of the former, and Gaspar and Melchor Pacheco. The resistance of those of the Maya who refused to accept Castilian dominion was overcome after several years of hard fighting, and San Francisco de Campeche, Mérida, the capital city, Valladolid and Salamanca de Bacalar were founded in rapid succession. A final desperate effort of the Maya of the eastern, central and southern provinces to drive the invaders from their lands late in 1546 was crushed, and henceforth the Castilians, now in considerable numbers and of a truly colonizing type, were secure in possession of the peninsula.

The *Adelantado*, who came of a family of the lesser Castilian nobility and who had served in Darien and Cuba, had been a captain under Juan de Grijalva and under Cortés in the earliest stages of the conquest of Mexico, and had represented the latter and New Spain at the court, was a man of wide vision, comprehension and moderation, a loyal servant of the Crown and an able administrator. He sought throughout to achieve the aims and policies of the Crown with regard to conquest and colonization, with which he was in full accord. From the first, complying with royal ordinances and laws and the provisions of his patent, he directed his efforts toward permanent colonization and the political

and economic development of the regions over which he was given authority, and he sought to protect the natives and further their well-being and Christianization. At the same time, he was ambitious and desired power, position and wealth, as did all the great captains who brought the Indies under the dominion of the sovereigns of Castile. Montejo the Younger and Montejo the Nephew were of the same basic character as the *Adelantado*, shared his aims and objectives and, as principal lieutenants, applied his policies. They were, moreover, capable soldiers and, like the *Adelantado*, able in administration. The characters of the *Adelantado*, his son and his nephew, it scarcely need be pointed out, exercised an important influence on the course of conquest and colonization.

The policies placed in effect by Montejo throughout his career are perhaps most readily delineated through summarizing the instructions for the conquest of Yucatan given by him to his son in 1540 on the eve of the final pacification and settlement of the peninsula. In these instructions the *Adelantado* provided as follows:

(1) That Montejo the Younger assure that the colonists live as true Christians.

(2) That upon arriving at the town of San Pedro, the advance base which had been established at Champotón, he should determine whether harm had been offered to the natives of the latter place, and that he should restore all property which might have been taken from them and free all who might have been illegally enslaved.

(3) That, because of the aid and support which they had given the Spaniards, the natives of Champotón should be exempt from all labor.

(4) That he should pass to Campeche, taking with him principal persons, or *principales*, of Champotón, where he should call together the lords of the area and inform them "how you go to people that land in name of His Majesty and to instruct them in the matters of our Holy Faith and that those who do not wish to

CALAKMUL, STELA 52

For many centuries the Maya erected stelae in their cities to record exact dates, those at Quirigua and Copan being exceptionally large. On these stelae were carved glyphs and, frequently, life-size and highly ornate human figures, perhaps of contemporary rulers or priests. The date recorded on the stela pictured here is 9.15.0.0.0 4 Ahau 13 Yax, or August 22, 731 (A.D.), according to the Goodman-Thompson correlation of Maya chronology with the Christian calendar. The Maya early developed mathematics to a high degree, and independently evolved the conception of zero and place-numeration, having 20 digits. They were able to make extremely accurate astronomical calculations.

PRESENT-DAY MAYA HOUSE AT VALLADOLID
Roofs are invariably formed of a framework of poles covered with thatch. The floors are of mud.

come to knowledge of God and obedience of His Majesty and those who do are to be well favored and protected and held in justice."

(5) That, accompanied by *principales* of Campeche and two of Champotón, he should enter the province of Acanul, taking great care that his forces offer no harm or ill-treatment to the Indians of that province, since they had always been at peace with the Spaniards and had desired that they settle among them.

(6) That in the province of Acanul he summon a certain lord, Chan Kan, a friend of the Christians who had aided them in time of war, who was to be well received, thanked for the good will which he had displayed, and kept with the Spanish forces as an ally.

(7) That he convoke the lords of the province of Acanul and inform them that they might have peace or war as they themselves determined and that if they came in peace they would be well treated and favored. If the native lords did not answer the summons, the formal *requerimiento* was to be published, as provided by the Crown, and should this be rejected war was to be made on them. In case war became necessary, it was to be conducted with as little harm as possible to both Spaniards and natives and in entire conformance with royal ordinances.

(8) That a city, which was to be the principal one of Yucatan, be founded at the town of T-hó if it appeared that the district was favorable for settlement. Efforts were to be made to win to peace the natives of the area in which the city was to be founded, but war was to be made on those who did not accept Castilian dominion.

(9) That upon the pacification of the provinces which were to constitute the district of the city, these were to be divided in *repartimiento,* according to prac-

tice, and that this *repartimiento* was to be made among not less than one hundred citizens, for, since the area was large and heavily peopled, a large number of *vecinos* was necessary for the subjection of the Indians and the maintenance of control.

(10) That the *repartimiento* be based on a general visitation of the conquered provinces and that after the number of towns and population had been ascertained *encomiendas* were to be assigned to the *conquistadores* in the name of the Crown in accord with the quality and services of those concerned.

(11) That, after the founding of the city, Montejo the Younger strive to have all the colonists develop agriculture and industry, he himself giving the example, and that roads be opened to Campeche, to the north coast and to principal towns.

(12) That the Indians be well treated, brought to knowledge of the Faith and under the dominion of the Crown, and drawn from their errors and evil practices.

All these things were to be done "placing God Our Lord before, and in service of His Majesty, for the welfare of the land, and in the fulfillment of justice."

The great conquests in the Indies were made at no direct cost to the Crown. They were achieved by the greater *conquistadores* upon their own initiative and at their own expense under specific authorization from the sovereign, granted in patents or, as in the cases of Cortés in Mexico and Alvarado, as a lieutenant of

PRESENT-DAY MAYA HOUSE AT CHAN KOM

The walls of the houses may be of frames formed of poles tied together with vines or other materials, sometimes covered with thatch or plastered with mud to render them more substantial, the mud usually being whitewashed with lime. Or they may be a combination of low walls of stone and poles which extend to the roof. In pre-Columbian times the common people lived in the same types of houses as those illustrated, as is indicated by Maya codices, mural decorations and elements of construction found in certain of the great buildings.

the former, in Guatemala, in the name of the Crown, and with *post facto* recognition. Those delegated authority to conquer and colonize designated areas financed and organized the expeditions for such purposes and in compensation were assigned revenues, privileges, lands and offices in the regions concerned. In their efforts the great *conquistadores* incurred heavy expenses. The expedition of 1527 organized by Montejo cost some 28,000 *castellanos*, secured by sale of inherited property, loans and funds supplied by his wife, and the Tabasco expedition of 1529 led to the expenditure of 12,000 *castellanos* more. Montejo's later efforts in Honduras-Higueras and Yucatan caused further and continued expenses, which were met only in part through revenues from the *encomiendas*, mines and land holdings which he acquired in Mexico, Tabasco, Honduras-Higueras, Chiapas and Yucatan. The *Adelantado* also came to an agreement with Juan de Lerma, a relatively wealthy merchant of Mexico, who, from about 1529 to about 1540, gave him material financial assistance. At the time of his death he was still some 30,000 *castellanos* in debt, despite his estates and holdings. He never received the four per cent. of the revenues of Yucatan as provided in his patent, and, indeed, it was not until he was close to the end of his career that the province was in a stabilized condition in which fixed revenues were forthcoming. Even then the *encomiendas* he held were removed from him under the New Laws of 1542–1543. The salaries and monetary grants received from the Crown in connection with offices held were always inadequate. Montejo the Younger and Montejo the Nephew in like manner financed the major efforts of conquest and colonization which they conducted as lieutenants of the *Adelantado* and likewise incurred indebtedness.

Those who took service under the greater *conquistadores* also bore their own expenses with respect to arms, horses, equipment and sustenance. Certain of the more important, as subordinate captains, raised companies and groups which they themselves equipped. The conquest of the southern provinces of Yucatan, Uaymil and Chetemal, by the Pachecos under authority of the *Adelantado* is an important example of such practice. Individual *conquistadores* also frequently brought with them squires and servants. Arms, supplies, horses and equipment, it should be pointed out, were normally extremely costly in the Indies. The soldier-colonists consequently, as well as the great captains, incurred heavy expenses and indebtedness.

Both the greater and the lesser *conquistadores* looked to the conquered lands and their peoples to afford compensation for the expenses which they incurred and the hardships and dangers which they underwent and to give recompense for the trials and uncertainties of colonization, and the Crown in granting or tacitly authorizing such reward achieved its purposes at no direct cost to the royal coffers.

The great *conquistadores* desired to achieve for themselves a position of maximum authority and influence and to obtain vested interests which should be based on the powers and privileges granted by the Crown and on their own achievements. The sovereigns, despite having in patents granted extensive authority and privileges to these individuals for the achievement of conquest and initial colonization, were determined to establish royal absolutism in its fullest sense in the New World. Consequently, to guard against the appearance of powerful vassals who might prove difficult to control and react detrimentally to their authority, after conquest and initial colonization had been carried out, they limited, restricted and revoked the powers and privileges which had been given and created a system of government which,

MAYA MEN AND WOMEN

Physically the Maya are short, thick-set and muscular, with relatively long arms and short legs. They are pronouncedly brachycephalic. The skin varies in color from light to dark brown. The upper jaw tends to be prognathous and the chin retreating. Eye-slits are horizontal or somewhat slanted, and the typical nose is prominent, high-bridged and quite curved in outline. The eyes are black and the hair is black, straight and coarse. As a race the Maya are characterized by pride, dignity and reserve. They are an extraordinarily cleanly people. In the picture women are wearing the white cotton *huipil*, which has been their dress from pre-Spanish times.

based on Castilian forms, depended directly and absolutely upon themselves. Columbus and Cortés had been shorn of real authority in accord with this policy, being permitted to retain only empty honors, and the *Adelantado* Montejo was dealt with in similar fashion.

Montejo early conceived the project of uniting under his authority as *Adelantado* the entire area from the western limits of Tabasco and Chiapas to and including Honduras-Higueras, with a corridor extending to the South Sea at the Bahía de Fonseca. This area was to constitute the *Adelantamiento* of Yucatan, the limits of which had been entirely undetermined in the *capitulación* of 1526. The career of Montejo in many respects centers about his attempts to achieve this great aim. Although it appeared possible of attainment at the outset, it was an objective which ran directly counter to royal policy with respect to government, and he inevitably failed.

In 1529, when on the point of passing from New Spain to Tabasco, the *Adelantado* first declared his broad territorial claims to the Crown, and in 1533, when permanent colonization of Yucatan appeared assured, he petitioned the sovereign that the area from the western limits of Tabasco and Chiapas to the Río de Ulúa be declared to constitute the *Adelantamiento*, maintaining that it was a geographic, ethnic and linguistic unit. The sovereign did not grant the petition

THE *CASA DE MONTEJO*, MERIDA
The construction was begun by the *Adelantado* shortly after the completion of the conquest.

of 1533 as such, but nevertheless in that year named Montejo royal governor of the region from the western limits of Tabasco to the Río de Ulúa, and later appointed him governor and captain general of Honduras-Higueras and united that province and Yucatan into an administrative unit under his authority. It is to be noted, however, that the position of Montejo as *Adelantado* applied only with respect to Yucatan proper, although pending final determination he was doubtless encouraged to believe that the lands beyond Yucatan, which had already come to connote only the peninsula, would later be declared by the Crown to be territory of the *Adelantamiento*. Moreover, it is to be borne in mind that when he assumed the governorship of Honduras-Higueras in 1537, Montejo had temporarily abandoned Yucatan and it was not until that year that Montejo the Younger took the first steps toward the reconquest. Pedro de Alvarado, Governor and Captain General of Guatemala, who possessed claims on the governorship of Honduras-Higueras and who at the moment enjoyed great royal favor, in 1539 forced Montejo to relinquish to him the governorship of Honduras-Higueras in return for that of Chiapas. This transfer was approved by the Crown. Upon the death of Alvarado, the *cabildos* of Honduras-Higueras in 1542 recalled Montejo as governor, and, after a confused jurisdictional controversy involving the *Audiencias* of Santo Domingo and Mexico, which had named governors to administer the province, his authority was confirmed in 1543 as a result of support given him by the former body. Meanwhile, Montejo the Younger, who since the abandonment of the peninsula had governed Tabasco as the lieutenant of his father, and Montejo the Nephew had carried forward, under the authority of the *Adelantado*, the final conquest and colonization of Yucatan. The position of Montejo from 1542 to 1544 was consequently extremely involved. He was, under separate appointments, at one and the same time, *Adelantado*, Governor and Captain General of Yucatan, Governor of the area between the

WOMAN GRINDING MAIZE
The great staple of all the aborigines of the New World. This method of grinding maize, employing the stone *metate* and stone roller, has been used by the natives for many centuries.

western limits of Tabasco and the Río de Ulúa, and Governor and Captain General of Honduras-Higueras and of Chiapas, and thus, as the result of a most intricate chain of circumstances, governed virtually the entire area which he had striven to erect into the *Adelantamiento* of Yucatan. He remained, notwithstanding, *Adelantado* of Yucatan, that is, of the territory of the peninsula, alone, and the Crown had not extended the territories of the *Adelantamiento*.

September 13, 1543, the Crown removed Montejo from all authority over Honduras-Higueras and Chiapas, and in May of 1544, upon the actual establishment of the *Audiencia*, of which his son-in-law, Alonso Maldonado, had been appointed president, he relinquished office. Authority over the area between the western limits of Tabasco and the Río de Ulúa was then taken from him, although he was permitted to govern Tabasco some time longer. Moreover, under the aegis

CHURCH OF SAN FRANCISCO AT MANI

Illustrating ecclesiastical architecture in an important Indian town. It was in the square in front of this church that Bishop Diegode Landa held his famous auto da fé in 1562, when 27 hieroglyphic manuscripts are said to have been burned.

In the interim the establishment of royal absolute government, in accord with Crown policy, had progressed throughout the Indies. The *Audiencia* of los Confines, later known as that of Guatemala, was created by one of the provisions of the New Laws to govern Guatemala, Honduras-Higueras, Chiapas, San Salvador and the other provinces of Central America, and Yucatan, hitherto within the district of the *Audiencia* of Mexico, was placed under its superior authority in judicial matters. By *cédulas* of

of Bartolomé de las Casas, the Dominican Order had secured authority from the Crown to reduce by peaceful means the region of Tezulutián, which was within territory which had been placed under the government of Montejo. All Spaniards other than friars were excluded from the region, which came to be known as Vera Paz. The district concerned, consequently, had been removed from the jurisdiction of the *Adelantado*. In 1547 Montejo sought to conquer and settle the general area of the Gulfo Dulce and des-

patched a large expedition which founded the town of Nueva Sevilla. The Dominicans immediately protested that the lands assigned to them were being invaded and their work destroyed, and they were supported by the *Audiencia* of los Confines, which, now under the presidency of Alonso López de Cerrato, an enemy of the *Adelantado,* also added protests of its own. The Crown ordered the evacuation of the area by Montejo, who had no alternative than to comply.

Upon the replacement of Maldonado in the presidency of the *Audiencia* of los Confines by Cerrato, the *Adelantado* was, under authorization of the Crown, removed from the governorship of Tabasco, despite his objections and initial refusal to recognize the authority of the *Audiencia* to take such action. At length, in 1549, as the result of charges concerning misgovernment, defiance of royal authority and other matters presented from many sources, among which was the *Audiencia* of los Confines, the Crown caused Montejo to be removed from office in Yucatan. His son and his nephew were at the same time stripped of authority. Montejo protested each successive removal from authority step by step, basing his claims on his *capitulación* and royal appointments, but to no avail. In a final attempt to regain his lost position he proceeded to Castile in 1551 to plead his cause directly before the Crown. There he died in 1553, at the age of about eighty. After the removal of Montejo from office, Yucatan passed directly under the administration of the normal agencies of royal government.

The Montejos, it should be noted, while in authority maintained firm control of the government of Yucatan in all its aspects, even to the extent of controlling the municipal councils, or *cabildos,* and they closely determined all the activities of the province. This close control aroused opposition on the part of a certain group of the colonists, who desired that the *cabildos* exercise a considerable measure of independence in local affairs in accord with Castilian tradition.

(To be concluded)

HUMAN PSYCHOLOGY AND SOME THINGS THAT FISHES DO

By Professor F. B. SUMNER
SCRIPPS INSTITUTION OF OCEANOGRAPHY

LET me, in my opening sentence, disclaim any pretence to be more than a dilettant in the field of psychology. However, I do at least claim to be a dilettant in this field, and as such I feel warranted in drawing some psychological analogies in discussing certain problems of fish physiology. Analogies may, of course, be illuminating or confusing, depending upon the phenomena under comparison. So far as the analogies may serve to emphasize points of resemblance which are really fundamental, they may be valuable clues to further discovery.

Despite the scorn for "introspection" on the part of some of those who call themselves "behaviorists," it would be difficult to investigate the phenomena of sense-perception in man without reference to what the subject says that he perceives. He tells us, for example, what color an object seems to him to have; whether this object appears to be larger than that, this light brighter than that or this sound louder than that. The subject's reports to us doubtless constitute a part of his "behavior" in the presence of these stimuli, but his reports would not be very illuminating to us if they were not expressed in terms of inner experience of a kind which duplicates inner experience of our own.

Unfortunately, we are unable to put questions, or at least verbal ones, to our fishes, with any reasonable expectation of receiving replies. But the animals are none the less able to inform us, to a certain extent, regarding their sense impressions. Needless to say, a fish's replies to our questions are given in physiological or behavioristic terms, with no mention of the creature's inner life. It is common sense, rather than scientific experiment, which leads us to believe that the fish is not a mere unconscious mechanism.

Some cases have interested me of late in which the quantitative relations between sensory stimuli and the physiological responses of fishes seem to be closely similar to those known to hold between these same stimuli and our own perceptions of them. And the correspondence in these cases is sufficiently striking to suggest that it depends upon essential similarities in the reactions of living matter in general.

Analogies of this sort may be of equal interest to the experimental psychologist and physiologist. The psychologist is vitally interested in the physiological concomitants of mental processes, and the physiologist doubtless profits at times by considering how physiological processes look from the inside. However, let us leave these easy banalities and consider some concrete cases.

The first of these cases is one which I have already discussed more than once in the past.[1] In fact, my interest in this particular problem dates from the year 1910. I regret that the coherency of my present discussion requires that I shall commence with some facts which are already familiar to most of you. Several groups of animals, and notably the fishes, display the capacity to adapt their shades, colors and even their skin patterns to the surfaces on which they happen to be resting. So important have these phenomena of color change become in the field of experimental biology that

[1] *Jour. Exp. Zool.*, 10: 409–505, 1911; *Physiol. Zool.*, 2: 495–504 (with A. B. Keys), 1929; *Biol. Bull.*, 65: 266–282, 1933.

their special bibliography must by this time exceed a thousand titles. Our recent symposium on this subject illustrates my point.[2]

We now have ample reason for believing that these color changes serve, among other things perhaps, the needs of concealment. In order that they may attain this end, it is obvious that the shade assumed by the animal must be constant, or nearly so, upon any given background, regardless of the intensity of the general illumination. This because both the animal and its background are equally affected by any change in the source of light. That such is the case, at least among the fishes, has been shown by abundant evidence. Under ordinary conditions, it is the shade of the background which influences the shade assumed by the fish. Within broad limits, the intensity of the incident light is found to play a very minor part in the matter. Thus the state of the fish's chromatophores is not determined by the absolute amount of light which reaches the animal's eyes, either directly from the source of illumination or by reflection from the background and surrounding objects.

Evidence from several sources makes it plain that the chief determining factor involved here is the ratio between the reflected and the incident light. This proposition is less simple, perhaps, than at first appears; for we can not credit the fish with any capacity to distinguish reflected from incident light, and to apply the proper correction for the intensity of the latter. On the other hand, the fish may be assumed to recognize differences of position within the visual field, and particularly the difference between up and down. The animal's response to the ratio *reflected: direct illumination* may therefore be supposed to resolve itself into a response to the ratio *lower: upper half of the field of vision.* Bearing in mind the inversion of the light rays within the eye, we have to do with the ratio of illumination between the upper and lower halves of the retina. That such a polarization of the retina, or possibly of corresponding areas within the brain, may actually exist is rendered probable by some experimental evidence.[3]

Several investigators, including the writer, have more or less successfully attempted to screen off one half of the field of vision by means of appliances covering the eye. Certain others have reported success in rotating the eyeball on its main axis through an angle of 180°. The upshot of these experiments seems to be that illumination of the upper and lower halves of the retina tends to call forth opposite responses on the part of the chromatophore system of the fish. Increasing the illumination of the upper half, relative to the lower, results in the paling of the fish; increasing the illumination of the lower half, relative to the upper, results in the animal's darkening. Evidence has recently been published, pointing to the existence of an actual morphological differentiation of these regions of the retina which may possibly be related to the physiological differentiation.

However, it seems doubtful, even for the fish, whether this problem of the correct perception of shades is fully explained by the simple assumption of a functional dorso-ventrality of the retina. That such an assumption would be altogether unwarranted in the case of man is quite certain. For it must be remembered that we encounter this same problem in relation to our own visual perceptions, albeit we humans, or at least those of the male sex, are unable to respond with appropriate changes in our pigmentation.

As Professor Woodworth has recently expressed the case:

[2] Am. Soc. Zool., Richmond, December 29, 1938.

[3] Sumner, *Biol. Bull.*, 65: 266–282, 1933; Vilter, *C. R. de l' Association des Anatomistes*, Marseille, March, 1937, pp. 1–14; Butcher, *Jour. Exp. Zool.*, 79: 275–297, 1938.

It is a fact of common observation that coal looks black even in sunlight and that chalk looks white even in shadow. Yet the light reaching the eye from well-lighted coal is very much stronger than that from shaded chalk. The retinal image of the coal is much brighter than that of the chalk, under the conditions, and the stimulus received from the coal is much more intense. One's impression conforms to the object rather than to the stimulus, and he is apt to see no problem here, for if coal is really black why should it not be seen as black in a good light? Not a bad answer, perhaps, but one involving some tacit assumptions that the psychologist would like to make explicit.[4]

Thus we have the much-discussed, if poorly named, problem of "color constancy" or, as it has been more technically termed, "phenomenal regression toward the real object."

To continue from Woodworth:

A certain mixture of white lead and lamp black reflects 25 per cent. of the light; its albedo measure is 25 per cent. It reflects more light, absolutely, when it receives more; but it always reflects 25 per cent. of what it received. If it is moved from a weaker to a stronger illumination, or the reverse, the observer still sees it as the same gray (approximately), thus in effect perceiving its reflecting power or albedo. We have been perceiving albedo all our lives without knowing it.

It is true that this correction for illumination is not always perfect. Under experimental conditions, the estimate of albedo is frequently more or less of a compromise between stimulus and objective perception.

That our correction for illumination is an act of conscious judgment is as little true for man as for the fish. The entire process takes place on the perceptual plane. We are influenced by various clues to general illumination, the nature of which has been studied in considerable detail by a number of investigators. It is impossible to discuss these clues here, except to say that they are provided by a variety of relations which may obtain among the contents of the visual field. No simple geometrical distinctions between upper and lower can be invoked.

If, by any device, the observer is deceived respecting the brightness of the light by which a given object is illuminated, his estimate of its albedo may be enormously in error. Black may look white, and white may look black. These illusions may be promptly dispelled by the introduction of suitable clues into the visual field, but they return immediately upon the withdrawal of the clues, despite the subject's full awareness of the deception.

Experiments in our laboratory and elsewhere have shown that fishes may be similarly deceived. In certain of these experiments,[5] the fish (one of the flounder group) rested upon a strip of clear glass, raised above an underlying gray surface, the latter being illuminated by a source of light invisible to the fish, and thus made to appear lighter than would have been possible if illuminated only by the source of light overhead. In these cases, the fish acted as if the substratum had been white, and assumed its maximum degree of pallor. When conditions were reversed, the fish darkened more than its background would have warranted, had the latter been normally illuminated.

There is another aspect of these color-change phenomena which finds a highly instructive parallel in the field of experimental psychology. Several years ago, we endeavored to determine what quantitative relations might exist between the visual stimuli to which our fishes had been subjected and the resulting effects upon pigmentation. It is now well known that prolonged subjection of fishes and amphibia to appropriate backgrounds may bring about very considerable changes in the actual amount of pigment possessed by these animals, in addition to the rapid rearrangement of pigment already present, such as results

[4] "Experimental Psychology," Henry Holt and Company, New York, 1938.

[5] Sumner and Keys, *Physiol. Zool.*, 2: 495–504, 1929. Confirmed in some essentials by Pearson, *Ecology*, 11: 703–712, 1930.

from briefer exposure to the same stimuli.

In the experiments under consideration, we have employed two methods of evaluating the effects of the stimuli in question upon pigment formation. The first of these was an attempt, thus far only partially successful, to assay the amount of the black pigment, melanin, present in a given lot of experimental fishes.[6] The second and more dependable method has consisted in counting the number of melanophores or melanin-containing cells present in a given area of the skin. In the course of these experiments, fishes of three different species have been subjected, on the one hand, to backgrounds of widely different albedo, the source of illumination being constant; on the other hand, to widely different sources of illumination with a constant albedo.

In the first type of experiment, the fishes were kept in glass aquaria, which had been painted black, white and two (later three) shades of gray, the specific reflectivity or albedo of each of these backgrounds being determined with approximate accuracy. In experiments of both types, the intensity of illumination from overhead was measured.

To state briefly the results of these experiments, we may say that the albedo of the background was found to be the factor of chief importance in determining the production or loss of melanin. (I speak of *loss* because the decrease of pigment upon a pale background is quite as conspicuous a fact as is its increase upon a dark background.)

The intensity of the incident light appears to be influential to a minor degree, at least in some cases. The extent of this latter influence will be the subject-matter of further experiments to be commenced in the near future. From the human analogy, we might expect to find such an influence, since the estimation of albedo is not entirely unaffected by the intensity of the illumination.

When the yield of melanin was plotted against the albedo of the background, it was at once evident that there was a consistent negative correlation between the two, the greatest yield being derived from the black-adapted fishes, the least from the white-adapted ones. It was equally evident that this was not a simple linear correlation, such that equal increments of albedo called forth equal decrements of pigment formation. The resulting curves looked suspiciously logarithmic, and this suspicion was borne out, for one series at least, when the data were plotted on logarithmic paper.

My most recent data, based upon the counting of melanophores, seem to confirm these earlier results very nicely. I think that we are justified, therefore, in concluding provisionally that melanin production (or loss) varies inversely as the logarithm of the albedo of the background. This conclusion is subject, of course, to the customary reservations: for the species under consideration, and within the limits of the stimuli here employed.

Now I am not one of those who believe that one's scientific respectability demands that he shall express all his results in terms of logarithms. In most cases, curves based upon natural numbers mean much more to me. But we all meet with occasions when the logarithmic arrangement of one's data is highly illuminating, and I believe that the present case is one of them.

Let us return to the field of experimental psychology. As a result of extended studies, E. H. Weber announced, about a hundred years ago, a generalization which has become famous in the realm of sense-physiology. The generalization was a simple one, and may be stated as follows: If, to a given stimulus S, we must add the value d, in order that the difference shall be just perceived by the subject, we must add not d but 10 d,

[6] Sumner and Doudoroff, *Proc. Nat. Acad. Sci.*, 23: 211–219, 1937; 24: 459–463, 1938.

if we start with a stimulus ten times as great. In other words, the increments of stimulus must be proportional to the original stimulus, rather than equal to one another, in order to bring about equal increments of sensation. In still other words, the increments of stimulus must be increased in geometrical progression, in order that the increments of sensation shall increase in arithmetical progression. Fechner expressed the matter in a simple equation: Sensation = C log Stimulus.

The Weber-Fechner law has, of course, been attacked on various grounds, logical and factual. On the former side, it is easy to see that just perceptible increments of sensation are not necessarily equal increments; on the latter, it is now well known that the "law" holds only for stimuli of medium intensity, but breaks down at both extremes. However, for present purposes we are not interested in such questions as the absolute magnitudes of sensations, while the generalization does hold fairly well throughout a wide range of intensities.

Thus far, then, we seem to have encountered two interesting points of agreement between our own sensory physiology and that of the fish. In the first place, we are both able to recognize the albedo of surrounding objects, regardless of their absolute illumination;[7] in the second place, the relation between sensation and stimulus seems to be, for both of us, a logarithmic one. I am quite aware that examples of the Weber-Fechner rule have been previously reported from the field of sub-human physiology, though none, so far as I know, in the realm of pigment formation. Endeavors have been made to interpret these relations on the basis of assumed physiological processes, but I believe that no proposed hypothesis has met with general acceptance.

Let us put some further questions to our fish, this time questions which have nothing to do with its sense of vision. If we raise the temperature of the fish's bath by ten degrees C., its consumption of oxygen will increase about three-fold; if we lower the temperature, a corresponding decrease will occur.[8] These facts, it is true, do not parallel what takes place when we subject ourselves to such temperature changes. Quite the reverse. In general, warming our environment lowers our metabolic rate, while cooling raises it. This, of course, is not due to any radical difference in the effects of temperature upon the protoplasm of cold-blooded and warm-blooded animals. It merely results from the possession by the latter of a heat-regulating mechanism which compensates for changes in the environment.

The parallel which I wish to draw is of another sort. When the fish is placed in warm water, its respiratory metabolism rises rather promptly to a maximum, and then gradually falls; though it never falls to a level as low as existed before the transfer. I must hasten to add that the term "never" applies here only to laboratory experiments, lasting a few months at most. The metabolic rate of fishes living in naturally warm waters—in warm springs, for example—is a subject which could be investigated very profitably. But whether it is complete or only partial, this physiological adaptation to higher temperatures is a process which can be readily observed and measured.[9]

Now let the human experimenter plunge his own hand into water considerably warmer than his skin temperature at that moment. He experiences a sensation which we are accustomed to call the sensation of warmth, and this, at the outset, may be very pronounced. But let him leave his hand in this warm water for a short time, and the intensity of the

[7] See also Burkamp (*Zeits. der Psychol. und Physiol. der Sinnesorgane*, 55 Bd., 1923, S. 133–170), whose experiments furnish evidence of a quite different sort for the perception of albedo by fishes.

[8] Wells, *Physiol. Zool.*, 8: 196–227, 1935.

[9] Sumner and Doudoroff, *Biol. Bull.*, 74: 403–429, 1938.

sensation diminishes rather rapidly. He, too, undergoes an adaptive change, such that the "physiological zero" or neutral point of sensation may be shifted by many degrees, and this within a few minutes' time.

Thus, the phenomena of temperature adaptation, in these two cases, present a very similar picture, although in one case we have to do with changes in oxygen consumption, in the other with sensory experience. We have, in each case, an abrupt rise in magnitude, followed by a more gradual fall. However, we are able to point out more striking similarities between these two sets of phenomena.

There is one type of experiment which we have performed many times upon fishes, and with consistently uniform results.[10] This is to transfer two lots of specimens which have sojourned some days or weeks at high and low temperatures, respectively, to a common intermediate temperature, and to determine their relative rates of metabolism after varying intervals. There is at first a complete reversal of the former relations, the fishes from the warmer water now having a much lower metabolic rate than those from the colder. After the lapse of a few days, however, these differences are obliterated.

Compare these findings with a classical experiment of Weber's, which most of us have doubtless performed. Let us immerse our two hands in warm and cold water, respectively; then, after a minute or two, plunge them both into water of intermediate temperature. The latter will feel at the same time cold to the one hand, and warm to the other, a reversal exactly comparable to that experienced by the fishes. Within a fraction of a minute, these differences will have vanished.

The relative rate of these adaptations in man and in the fish might seem to throw them into quite different categories. Those in man are to be measured in minutes or even seconds, and seem to be primarily phenomena of the nervous system. Those in the fish, on the contrary, cover days or weeks. They are very questionably to be ascribed to the nervous system, despite the far slower tempo of nervous processes in a cold-blooded animal. Nevertheless, both are excellent examples of physiological temperature adaptation, and it hardly seems likely that the analogy between them is entirely superficial. The various phenomena of contrast and negative after-effects are familiar both in physiology and psychology, and the physiological mechanisms which underlie them are not altogether unknown.

* * * * * *

Thus far, however, we have been traveling in waters which have been sufficiently charted to give us at least a comfortable sense of security. We could see enough beacons and lighthouses in various directions to keep us from being stranded on the shoals or dashed to pieces on the rocks. We might never have reached the promised land, but at least we were never in danger of shipwreck.

I am going to ask you now to sail with me upon a cruise of reckless adventure, with nothing but dead-reckoning to guide our course. Your captain is painfully inexperienced and possibly even subject to hallucinations. Also, the mate tells me that the rudder has been lost. We shall embark from the harbor of solid fact, and end, perhaps, in the fog of phantasy. Are you ready?

Let us commence with one of the more spectacular performances of fishes. I refer to the spawning migrations of the salmon.[11] The story has often been told, and you are all doubtless more or less familiar with it. Perhaps the oft-repeated assertions of certain critics may have led you to believe that the essential

[10] Wells, *Biol. Bull.*, 69: 361–367, 1935; Sumner and Wells, *ibid.*, 368–378; Sumner and Doudoroff, *Biol. Bull.*, 74: 403–429, 1938.

[11] Since a comprehensive review of the literature of this field has recently been prepared for *The Quarterly Review of Biology* by Mr. Bradley Scheer, I have not thought it worth while to cite references here.

features of this narrative are still in doubt. While I altogether lack personal experience in this field, I think that a careful reading of the evidence will convince most biologists of the validity of the so-called "home-stream theory."

The amount of sound observation and well-planned experimentation upon which this theory is based is very great; and while certain inevitable gaps exist in the continuity of the direct evidence, there appears to be considerable indirect evidence which serves to fill in these gaps. On the other hand, such limited negative evidence as has been published would seem to apply only to particular streams or particular local populations of salmon, and it certainly does not invalidate the far larger mass of positive evidence. I shall speak chiefly of the Pacific salmon, since our best evidence has been derived from these.

Here, then, are some of the facts. Young of several species of Pacific salmon have been marked in lots of many thousands at a time and liberated at various points in a number of the river systems of British Columbia and our own Pacific states. Many of these individuals have been recovered upon their return from the ocean to spawn several years later. With insignificant exceptions, such fishes have been taken in the river system in which they were planted, the exceptions relating to streams in the immediate vicinity. Moreover, they were taken very preponderantly in the same tributary in which they were planted.

"The most striking instance of this return to the home-stream," say Rich and Holmes,[12] "is that to Spring Creek. This stream is so extremely small that it is difficult to see how the salmon could find it at all, and yet 82 of the fish marked here were recaptured here as adults, while only 4 were taken in other spawning tributaries."

However, this specificity, in relation to the particular tributary, is not always as precise as in the case cited. It seems to depend, in some measure, upon how long the young fish stays in the stream before its migration to the sea. One highly important fact must be stressed here. Transplantation experiments with young bred in the hatchery have shown that it is not necessarily the home-stream of the parents to which the spawning adult returns. It returns to the stream in which it spent its own early life after hatching.

The facts thus far stated would not be so difficult of explanation if it could be assumed that the marked fish, after its descent to the ocean, never ventured far from the mouth of its home stream, but remained within the latter's zone of influence until the spawning instinct prompted it to seek fresh water again. Even then, we should be left with some tough problems to solve. Unfortunately, no such assumption is warranted. Many of the marked fishes have been trapped at distances of hundreds of miles from the river's mouth.

Certain writers, apparently wishing to save their faith in the simplicity of biological phenomena, have contended that all such specimens must necessarily be "strays," which could never have made the home journey. But such a claim is purely gratuitous. Salmon which have been tagged in the ocean as adults, as far away as Queen Charlotte Island, more than 600 miles distant, are known to have entered the Columbia River to spawn.

Moreover, the proportion of these "strays," in some experiments with the Atlantic salmon, is known to have reached as high a figure as 30 per cent. of those recovered, certainly an unexpectedly high proportion of biological wastage, if the contention of these critics be granted. And again, one may ask, why should not these supposed stragglers, under the urge of the spawning instinct, seek fresh water and attain their end in the nearest available river? Apparently, this never happens.

Further important indirect evidence

[12] *Bulletin of the U. S. Bureau of Fisheries*, 44: 215–264, 1929.

is derived from a study of the scales and some other characters of the salmon, which indicate that the fishes of different rivers, even those belonging to the same species, exhibit recognizable racial differences. It is significant that mixed populations, comprising a number of these local races, have been found on oceanic feeding-grounds, far from these various home-streams. It would certainly be difficult to account for the maintenance of such races, except on the supposition that they segregate themselves and travel independently to their respective streams at the time of spawning.

In the present state of our evidence, I think that we can hardly escape the conclusion that the individual salmon commonly returns to spawn in the same river and tributary in which it passed its early life, and this even after the lapse of several years spent in the ocean, and after migration to points which may be hundreds of miles distant.

The difficulty of accepting this conclusion results, of course, from the difficulty of accounting for the phenomena concerned. And yet we have difficulties of a similar nature, and perhaps even greater ones, in the now well-known life histories of the American and European species of fresh-water eel. Here, the mature fishes, after a life of many years in the fresh-water streams of America and Europe, return to spawn in the region of their nativity in the western Atlantic, in many cases after a journey of several thousand miles. But that is not all. The young of these two species, with no parental coaching, except what is conveyed through the genes, reach in time their own proper sides of the Atlantic and ascend the rivers. We will not say the same rivers in which their parents had lived. That would seem to be too much to ask of them, though it would be an impossible thing to prove if they actually did it.

The different life-histories of these two species depend in part upon differences in the length of the larval period, that of the European eel lasting about three years to the American's one. And the northeasterly migration of the European larvae is partly passive, being aided by the Atlantic drift. Yet neither of these circumstances helps us very far toward an explanation. We must recall that the eggs of the two species are laid in contiguous or even overlapping areas of the ocean and that the young larvae mingle together freely at first throughout a considerable area.

It is true that attempts have been made to force a certain part of these facts into our previously accepted categories and to question the others. Writers holding this point of view would account for the return migrations of the salmon as a succession of thermotropic or chemotropic responses. One prominent American biologist, for example, has contended that at each fork of the road the fish selects the colder water, while a French writer seems equally convinced that it is the proportion of oxygen which each stream carries that is determinative in the choice. Such suppositions can hardly explain how a number of races may make different selections at the same crossroads.

That the phenomena of salmon migration do not fit into these or any other established physiological categories would seem evident from a brief examination of the data already known. On any theory, we must grant the existence of some sort of organic memories or "engrams," recorded in the nervous systems of the fishes, since the return journey is so largely dependent upon the individual's early history. These memories must relate, in some way, to the individual's past experiences of the environment. According to our familiar modes of interpretation, they must enable the animal to recognize very specific elements of this environment, to the extent that they are able to trace their early wanderings in reverse. But this would necessitate the supposition that the essential elements of the fish's early environment, and the rela-

tions among these, remain essentially unchanged during the animal's long absence. This plainly can not be the case.

Let us, for example, suppose that the fish "remembers," albeit unconsciously, the quality of the water of its home river and tributary creek, and is able to distinguish this from a great variety of other waters through which the nostalgic creature passes on its return journey to spawn. Such a supposition would not be incredible, perhaps, if we could assume that the sought-for water retained its old-time flavor. But suppose, as actually happens, that the young fish left the river in the fall, whereas it returned in the spring, when the water temperature was much lower. In such a case, too, the downward migration must have taken place during a period of low water, whereas, at the time of the return journey, the spring freshets had perhaps quadrupled the river's flow, stirred up much silt, aerated the water more thoroughly and in general changed its chemical and physical properties. Then, too, forest-fires on the watershed, and changes due to agriculture or to industrial development can not fail to modify the composition of the water from one year to the next. These resulting fluctuations in the character of the water of any single river may surely lead to greater diffierences at times than those which distinguish one river from another.

How, then, can we resolve these directed wanderings of the salmon into a mere succession of thermotropic or chemotropic responses, when there is no constancy in the physical conditions of any part of the travel-route from month to month or year to year? I don't believe that this can be done.

I have spoken of the thermal and chemical senses in this connection, since any other known special senses of the fish may be safely left out of consideration. Many persons, particularly those without biological training, are quick to appeal to some unknown "sixth sense" to help us out of such a situation. As if most vertebrate animals, fishes included, did not have more than six senses already!

The question in this case is not so much that of discovering some additional sensory mechanism in the fish as it is of finding, or even conceiving of, some hitherto unrecognized mode of physical energy competent to act as a directive stimulus. I think that we are justified in saying that we lack any satisfactory clue to such a directive stimulus at the present time. The situation might seem to call for some method of geodetic orientation upon the earth's surface rather than mere guidance by stimuli from successively encountered features of the environment. But orientation in the earth's magnetic field would surely be a wild guess, and guidance by means of the earth's rotational forces would perhaps be an even wilder one. And what would you think of me if I should attempt to endow the poor fish with some sort of an integrating mechanism, such as our mathematical friends employ in their calculations—one which would automatically register all the components in the animal's meanderings and come out with the right answer, in spite of everything? Alas, though the fish's anatomy is pretty well known, there doesn't seem to be room anywhere for an integrator.

Whatever unknown or unsuspected factors may be operative, however, we may be certain that the animal's recognized senses supplement these and play an important part in the matter, throughout. Above all, it should be insisted that this entire range of phenomena lends itself very well to experimental attack. Various hitherto untried experiments suggest themselves, which would go a long way towards clearing up some of the more baffling points.

* * * * * *

I am next going to take you on what some of you may regard as a brief trip through the scientific underworld. Before permitting yourselves to be shocked

or indignant, however, I beg of you not to form premature notions of my real meaning.

There is still a wide-spread belief, dating from man's earliest past, that we have channels of knowledge independent of our recognized senses. This belief would seem to have all the earmarks of a primitive myth, and I am not prepared to say with full confidence that it is not precisely that. However, it is a curious circumstance that evidence for phenomena of this type has been accumulating in our present scientific age, and indeed in the hands of some of the scientists themselves. Experimental methods have been applied, sometimes with every appearance of honesty and intelligence, and results obtained which have seemed conclusive enough to convince men of high standing in their own special fields of science. Our great psychologist, William James, for example, unhesitatingly expressed his belief that the "medium" (or her "control") might be "acquainted with facts about the circumstances, and the living and dead relatives and acquaintances, of numberless sitters whom the medium never met before, and of whom she has never heard the names."

One may, of course, cite James as a striking instance of how a brilliant and learned man may allow himself to be woefully deluded, and this may, indeed, prove to be a just appraisal of his case. However, I should insist that no one is entitled to offer such an opinion unless he has at least taken the trouble to examine the evidence on which James based his beliefs.

As many of you may know, there is a rather steady output at the present time of alleged proofs of the reality of both telepathy and clairvoyance. Such claims are not restricted to "swamis" and Gypsy princesses. They are being made by men holding chairs in some of our more reputable universities, and they purport to be based upon rigidly experimental procedure. The claims of Professor Rhine, of Duke University, are probably the best known in recent years,[12] but similar results have been announced from various other sources which would ordinarily be calculated to inspire confidence.

We are assured, for example, that a certain proportion of the subjects who have been tested in this connection are able to designate cards of a special set considerably more frequently than would result from mere chance guessing. In some of these tests the subject and the experimenter were in different rooms or in different buildings or were even miles apart.

Particularly bewildering to us would be admission of the claims of clairvoyance. It is alleged that certain of these subjects possess the ability to penetrate the depths of a pack of the experimental cards and to discern, preponderantly at least, the order in which they chance to lie. No form of radiant energy would seem competent to reveal to a sentient being the differences of pattern in cards lying at successive levels in a pack, a fraction of a millimeter apart. Think what a jumble an x-ray photograph would make of such superimposed patterns!

On the whole, these experiments have every appearance of being conducted honestly, and with a serious endeavor to exclude the numerous opportunities for self-deception. Statistically speaking, they would seem to have vastly higher evidential value than we ordinarily demand in an experimental research in biology.

Where, then, is the joker in all this? I confess that I do not know. It would relieve our minds vastly, of course, if we could accept the most obvious explanation, that of fraud. If it is fraud, it has been conducted on a rather large scale, and in some quite unexpected places. In

[12] "Extra-Sensory Perception," Boston, 1934; also articles in *Jour. Parapsychol.*, published by Duke University, Durham, N. C.

some of the cases, it must have involved conspiracy on the part of a number of persons. Self-deception is another familar mode of explanation, and a far more charitable one, but it is not at all easy to reconcile this with the published accounts of the procedure. These are more easily reconcilable with intentional deceit.

It is my guess that a large majority of those here present will be content to dismiss the subject with one of these alternative explanations—fraud or self-deception. I wish that I could be satisfied with such a ready solution of the problem. It is my impression that this type of solution is less acceptable in proportion to one's familiarity with the evidence. And in so saying I by no means restrict myself to the evidence of the past few years.

Now I can feel—and this without any recourse to telepathy—that some of you are bewailing my folly in giving serious attention to such a thoroughly "screwy" subject before an eminently respectable scientific gathering such as this. However, please remember that I came to you primarily as a student of fishes, and that it is the time-honored privilege of one who talks about fishes to depart from conventional notions of credibility. Now and then, too, the narrator of fish-stories it able to confound his listeners by showin them that the incredible is true, as witness the homeward migrations of the larval eels, already referred to, or the story which I have just related of the return of the spawning salmon from the ocean to the old swimming hole, in that little creek, hundreds of miles upstream from the river's mouth. But you don't have to take the word of the fish man for the reality of these incredible performances among animals. The ornithologist has long told us impossible things about the migrations and homing instinct of birds, and in recent years he has been able to back up his assertions experimentally by the use of the banding method.

Before concluding, I hope that I may be able to dispel any misunderstanding as to what I have been trying to tell you in this last section of my address. I am not asserting that any experiments in the field of telepathy and clairvoyance yet stand on the same footing scientifically as those of the salmon-taggers or the bird-banders. Nor do I say, or even imply, that these fishes or birds are guided by any such faculty as that which (*perhaps!*) enables our clairvoyant friends to see through their packs of cards or to filch perceptions at long range from the interior of one another's craniums.

My intention, in this last section of my address, is to insist upon the possibility that in both man and some other animals, impressions from the environment may not all be mediated through recognized organs of special sense which are sensitive to recognized modes of chemical or physical stimulation. This does not mean that I wish to remove a large and important class of phenomena from the field of natural science. There is abundant opportunity for rigidly exact investigation here, both in the case of man and fish. And I believe that it is our present duty to settle some of these highly controversial matters by experiment, instead of dogmatically denying them or complacently ignoring them.

You may think that these remarks of mine are merely the maunderings of a senescent brain. If so, my brain began to senesce many years ago. However, it is a popular belief that willingness to entertain strange and unwelcome ideas is a quality of youth rather than of old age and that the real attributes of senescence are bigotry and intolerance to new modes of thought. And so I will rest my defense on the plea of extreme youth and throw myself on the mercy of the court.

TIME AND PLACE FACTORS IN EARLY HUMAN EMERGENCE

By Professor PAUL HUSTON STEVENSON

DEPARTMENT OF ANATOMY, PEIPING UNION MEDICAL COLLEGE, PEKING, CHINA

THE quality of interest being displayed at the present time in the various problems pertaining to early human history differs in kind and degree from that of any preceding age. Although innumerable generations have rendered lip service to the classic admonition "know thyself" —carved by unknown hands above the entrance to Apollo's temple in ancient Delphi and proclaimed by Socrates to be the beginning and the end of the pursuit of knowledge—yet it has remained for the present generation to bring to bear on this central problem of human interest a discipline of factual thinking that is destined to remove the problem, for all time let us hope, from the realm of mere philosophical and metaphysical speculation. This fortunate circumstance, the significance of which it would be difficult to overemphasize, has not come about fortuitously. During a relatively brief period of years, not exceeding two or three decades in certain fields of investigation and hardly more than as many centuries in others, man has acquired a keener sense of reality and a deeper respect for the forces inherent in nature than he has ever had before. His growing understanding and confidence in the essential integrity of natural law, including even the laws underlying the mysterious phenomenon of life, are such that in spite of his fumbling efforts to interpret the evidence dealing with his own existence, man nevertheless feels no longer impelled to divorce himself from the rest of nature and ask the intervention of a supernatural order on his behalf.

Among the various questions relating to early human history, there are two in particular about which the interpretation of the available evidence has up until now been particularly difficult. These are, briefly: (1) *when*, in geological history, did there appear on the scene those unique creatures whose sum-total of physical and mental attributes, so far as we may surmise, entitles them to be considered the earliest members of the human family; (2) *where* on the earth, with due consideration of the paleogeographic alterations in the various land masses involved, did there exist the particular combination of circumstances most likely responsible for the ultimate differentiation of these early hominid forms from the parent Primate stem. In brief, today, we are still asking, as thinking man has probably always done, about the when and where as well as the whence of the coming of mankind. The significance of *Sinanthropus pekinensis*, the best documented of the early fossil hominids thus far discovered, resides largely in the fact that this primitive form contributes significantly to the answers to these questions.

The comparative wealth of *Sinanthropus* fossil remains now available enables human paleontologists to define its distinctive characters and to determine that it represents without doubt the earliest hominid type yet discovered under circumstances conducive to a distinct advance in knowledge concerning many of the special questions involved. Its contribution to the first of the questions mentioned above, namely, that of the time element in early human evolution, resides in the simple but significant fact that the remains in question were found firmly

embedded *in situ* in the undisturbed geological formation of the time during which this creature lived. The definite geological age of this formation is amenable to determination in accordance with usual paleontological procedures. The fortunate circumstances under which the *Sinanthropus* remains were discovered are in sharp contrast with the considerable uncertainties respecting the geological formations yielding the remains both of *Pithecanthropus* of Java and *Eoanthropus* of England. Both these latter finds were recovered from beds of redistributed gravels. Therefore, in addition to certain controversial questions relating to these respective finds on morphological grounds, there will always remain a considerable degree of uncertainty regarding their actual geological age.

With regard to the age of man as disclosed by *Sinanthropus,* on the basis of careful study of the stratigraphical and paleontological evidence the Choukoutien fossiliferous deposits containing the remains are assignable to the early stages of the Pleistocene period of geological time. If we accept the latest geochronological estimates based on radio-activity determinations, then we must assign to *Sinanthropus* an age approaching very nearly one million years.

This figure is of significance chiefly when compared with earlier estimates of the time of human origins, or when considered in relation to either the age of the earth or the estimated span of total life history on the earth. Compared to earlier estimates this newly determined age of man is much greater than hitherto assumed. Indeed, the figure is two or three times that given in many present-day treatises dealing with the subject of early man. A million years, however, is none too long a time for the significant morphological changes that have taken place in the human organism since *Sinanthropus.* There will perhaps always be a considerable range of variation in expert opinion bearing on the point in question. Estimates of the exact age of man will probably always vary as much as from a quarter to a half million years. It must be noted, however, that each successive geochronological determination increases rather than decreases the probable duration of the various divisions of the total life period and correspondingly that of man. The significant fact is that when compared with either the total age of the earth or the span of life on the earth—ages estimated by the latest radio-activity methods of determination as approximating 2,000,000,000 and 600,000,000 years respectively—then it must be realized that mankind, with barely one million years to his credit, is among the very youngest of the distinctive animal forms inhabiting the earth to-day. And when contemplating the various problems besetting the human family, it is well to appreciate the fact that this extreme *youthfulness* of man, which in many respects is his most significant paleontological characteristic, must at the same time be counted his greatest asset.

Of slightly different order but of equal interest with that of age is the question of the *geographical region* and the relevant circumstances giving rise to the hominid divergence from the proto-human Primate stem. Various localities, usually either in Asia or Africa, have at one time or another been suggested as the site of this significant evolutionary step. I shall in this place briefly outline the evidence which seems to point to-day to that region of Asia north of the Himalayas as the area in question. The evidence consists of correlated data derived from three fields of inquiry, namely, zoological, geographical and paleontological. The essence of these correlated findings are briefly as follows:

The largest land area on the earth's surface, namely Asia, particularly the central area of this vast continent, has long been recognized as bearing a peculiarly significant relation to the geo-

graphical distribution of animal life. This is true with respect to both living and extinct forms. An examination of the distribution of land and water areas of the earth's surface reveals the fact that all the great land masses of the earth are contiguously related to Asia in the northern hemisphere, in spite of occasional separations due to recurrent transgression of the oceans over certain shallow areas; whereas the radiating continental extensions below the equator in the southern hemisphere are separated from one another by wide and deep oceans.

The sequence of events relating to the history and dispersal of the various mammalian forms over these related land areas was set forth most clearly by W. D. Matthew in his historical treatise in 1915 on "Climate and Evolution." The evidence bearing specifically on the problem of the history and distribution of the Primates was later assembled and discussed by Davidson Black in a valuable paper "Asia and the Dispersal of Primates." Both these publications are destined to become classic contributions in their respective fields. They have established beyond reasonable doubt that climatic change must be considered a most significant determining factor in the evolution of land vertebrates and "the principal known cause of their present distribution." The correlated evidence points clearly to the additional fact that "the principal lines of migration in later geological epochs have been radial from Holarctic centers of dispersal"; in many specific instances, it may be added, from the central Asian region of the Holarctic zoogeographical distribution zone. Black was aided greatly in his discussion of the distribution of the various evolving groups of the Primates throughout Cenozoic time by Grabau's paleogeographical maps of Asia covering this period.

The particular findings concerning the relevant events that appear to have been taking place at the critical period of Primate evolution, the period during which the proto-human stock became differentiated from the main Primate stem, may be summarized somewhat as follows: During the uniformly warm and moist Eocene and immediately succeeding periods up to middle tertiary times and before the elevation of the Himalayas, the Asian landscape appears to have presented a relatively simple topography. The climatic conditions over most of this area, at least as far north as the Siberian border of to-day, were such as to favor an extensive forest growth. These facts are attested not only by the fossil records of the plant life in the Oligocene coal beds of Manchuria and other regions of North China but by the distribution of fossil remains of certain browsing animals, among them the giant hornless rhinoceros *Baluchitherium*. Fossil records indicate further that during the early periods of the Cenozoic this extensive area was also the site of a rapidly expanding phase of higher Primate evolution.

In spite of the delayed paleontological exploration of certain portions of the area in question, particularly the Tibetan plateau and adjacent regions difficult of access at the present time, the accumulating fossil records of this critical period in Primate evolution are consistently significant in their direct bearing on the problem of proto-human evolution. The area of greatest concentration of fossil remains of the highly specialized Miocene anthropoids is located in the Sivalik region to the south of the present Himalayas. The faunal and floral conditions making up their natural habitat, as well as that of their immediate descendants, extended at that time uninterruptedly to the north. There is little room for doubt that the remains of these advancing Primate forms will in time likewise be found in the contemporary deposits of the unexplored

contiguous areas in that direction. The fact that *Dryopithecus* has been found as far away as Europe, in the late Miocene strata, is evidence of the fact that these forms were able to migrate widely over their range of suitable environment.

Certain generalizations based on the correlation of these biologic and paleogeographic factors become inevitable. It is generally conceded, for instance, that the most conspicuous morphological and related changes leading toward human evolution were those occasioned by man's pre-human ancestors leaving the forest and adventuring into the open. These morphological changes, made necessary by gradual alterations in the type of habitat, were of the nature of progressive adaptations through the development of potential though dormant faculties. Perhaps the most significant of these dormant faculties, from the immediate functional standpoint, was that of a lower extremity capable of being specialized for unassisted support and progression. Such specialization of the lower extremity made possible in turn the subsequent emancipation of the forelimb, and released the evolving potentialities of the human hand. Important also among the attributes of greatest potential significance were eyes that had already moved around to the front of the head, thus permitting a more perfect stereoscopic and otherwise discriminating visual examination of nature. But of greatest significance of all these proto-human Primate attributes was a brain possessing a cerebral cortex capable of the elaboration of association areas under an increasing influx of new and discriminative sensory stimuli. These and other associated morphological and physiological potentialities were among the faculties of the arboreal anthropoids making up the proto-human Primate stem.

There is no one better qualified to formulate the paleogeographical and climate changes that brought these evolutionary factors into existence than Professor A. W. Grabau, whose critical consideration and first-hand examination of the evidence relating to the points at issue have extended over nearly two decades of intensive paleontological research in China. Expressed in his own well-chosen words these formulations are as follows:

> It is however a pertinent question which can not be lightly put aside: what would induce the primitive anthropoids to leave the forest and adventure into the open where the necessity of a radical change of habits would confront them? It is inconceivable that forest-dwellers, finding all their needs of food and shelter supplied in their forest homes, could be induced voluntarily to leave it, nor could we assume that they were driven into the open, as long as forests remained anywhere for them to take shelter in. It is only the wholesale destruction of the forests, and the development of barriers which would prevent migration to forested countries elsewhere, that could force these primitive anthropoids to assume a new mode of existence, and compel those capable of adapting themselves to the new conditions to enter the path of development that would ultimately lead to man.
>
> The elevation, at the beginning of Miocene time, of the Himalayan Range across Southern Asia would have precisely the effect postulated above as necessary to initiate the new line of development. These mountains intercept the moisture-bearing winds from the Indian Ocean. . . . Infrequent rainfalls and the drying up of lakes and streams, would lead to a depression of the water table, with the accompanying destructive effect upon the vegetation. With progressive increase in aridity, the destruction of most if not all the forest trees was brought about. . . .
>
> I submit that it is the isolation of the Tibetan region, by the elevation of the Himalayas and other mountain ranges, and the accompanying increasing aridity which produced the environment which alone could lead to the emergence of the human type. And I further maintain, that unless it can be shown that Africa or any other region of the world experienced a parallel change in its geographic and climatic conditions at the crucial time, these regions can not lay any claim to being the site of man's emergence comparable to that offered by Tibet and the adjoining districts of Asia.
>
> But while the survivors north of the Himalayan Range were forced into this new path of evolution by the radical change in environment, those on the south met with little change in the

conditions of existence. Development proceeded entirely along the established lines of simian characteristics, and it can scarcely be doubted that the existing great anthropoids arose from ancestors that remained on the south of the Himalayan barrier or migrated to regions open on the east and west.

Sinanthropus pekinensis, the most primitive hominid of which we have specific or detailed knowledge, therefore requires no forced explanations as regards either his morphological status, his geological horizon or his geographical location. The various factors associated with his discovery are consistent throughout with respect to either or all of these points. And the intensive studies of the morphological details of this unique form that are now being carried on by Professor Franz Weidenreich, able successor to the late Davidson Black, are destined to increase greatly our knowledge and appreciation of the significance of the skull, brain and dentitional stages of development found in this exceedingly primitive type of early man.

The gap that separates *Sinanthropus* from the nearest known anthropoid forms of lower status is distinctly greater than that separating him from the other fossil hominids of more advanced status. When it ultimately becomes possible to carry out extensive paleontological explorations in late Pliocene and early Pleistocene deposits in regions further west, on the Tibetan plateau and in central Asia, the more immediate ancestors of *Sinanthropus* may be looked for with a very reasonable assurance of their being found. There seems little hope at the moment, however, that circumstances will prove favorable in the near future for such explorations. In the meantime the fossil remains of various migrants from this area, representing no doubt in certain instances the descendants of intermediate forms between the highly advanced *Dryopithecus* anthropoid forms on the one hand and *Sinanthropus* on the other, will be found in near or far regions of the earth. There is some indication that the fossil form *Australopithecus,* found in Africa, may represent such a stage. Considering the vastness of the time involved, there is nothing inconsistent in the discovery of this advanced proto-human form in Africa and the postulated Asiatic origin and area of dispersal as set forth above.

On the basis of the relevant paleogeographical and paleontological data now available, therefore, the following tentative chronological outline of probabilities seems to be justified with reference to certain cardinal factors underlying late proto-human and the early human stages of evolution. Professor Grabau's summaries of the periods involved will be used, and his term *"Protanthropus"* retained as a designation of the earliest hominids.

(1) *Oligocene period:* "Asia mostly a continent of undulating wooded and well-watered lowlands and fertile plains, without high mountains, separated from Europe by marine straits. Primitive anthropoids like *Dryopithecus* inhabited the forests, and *Baluchiterium* roamed the plains."

(2) *Early Miocene* (B.C. 20,000,000 or earlier): "The Himalayas and other mountains arose in Asia, the Alps, Carpathians and others in Europe. Increased rainfall over northern India, aridification of climate over Tibet and much of Central Asia. The death, by drought, of the forest trees, forces the surviving anthropoids into the open, while *Baluchitherium* becomes extinct. *Dryopithecus* remains largely unaffected and unchanged in the region south of the Himalayas."

(3) *Later Miocene:* "Increasing aridity forces the surviving anthropoids in Tibet, etc., to adapt themselves to the new environment or perish . . . *Protanthropus* emerges . . . South of the Himalayas, anthropoid development proceeds along Simian lines."

(4) *Early Pliocene: "Protanthropus* migrates northward and reaches the well-

watered Tarim basin." While supported as yet by no direct fossil evidence, this hypothetical generalization is nevertheless fully in accord with all relevant subsidiary evidence.

(5) *Later Pliocene* (B.C. 10,000,000–B.C 1,000,000): "*Protanthropus* starts his migration east and west, divergent modification characterizing the various branches." The earliest flint industry probably begins during this period and develops unequally in various regions.

(6) *Polycene* (a period of transition designated by Grabau between the *Pliocene* and *Pleistocene* in Asia) (B.C. 1,000,000–B.C. 500,000); "Descendants of *Protanthropus* reach east China as *Sinanthropus*. A branch starting southward reaches Cathaysia where tropical conditions induce retardation in development, and *Pithecanthropus* emerges. The westward migrating group splits, one division reaches west Europe as *Eoanthropus* —(possibly with a branch ending in *Palaeanthropus*); another enters Africa and develops features characteristic of *Homo* but retains a primitive culture."

(7) *Pleistocene* (B.C. 500,000–B.C. 100,000): "Glaciation of Europe. . . around the borders of the ice sheet Neanderthal man develops his culture. Cold dust-laden winds, depositing enormously thick layers of loess, prevented Neanderthal migration to China where *Sinanthropus* may have continued or become extinct. . . . The dismemberment of Cathaysia isolates *Pithecanthropus* who either becomes extinct or under island environment develops an independent Neanderthaloid type."

(8) *Early Holocene* (B.C. 100,000–?): "The waning of the ice sheets puts an end to the dust-bearing winds, or greatly diminishes them. Neolithic man migrates to Europe from the still unknown center of his origin . . .," and also, it may be added, to eastern Asia, where he and his cultures became wide-spread.

(9) *Later Holocene:* "Civilization emerges."

In the preceding paragraphs we have attempted to fit together certain fragmentary fossil records and the correlated paleogeographical evidence that are now available relevant to the very earliest stages of human emergence. From the seventh (Pleistocene) stage in the foregoing chronological outline onward to the present, the footsteps of primitive man become more and more distinct, although wandering for long periods of time along trails that are still obscure.

Despite dire prophecies to the contrary there is no reason to doubt that human evolution still continues forward and upward. Generation after generation of mankind persistently come and go. Each contributes its mite of human experience to the accumulated progress achieved by the countless generations of the past. Continued progress depends as ever on infinitely small increments, derived from individual successes in meeting the physical, mental and social challenges of a changing world. The human cerebral cortex strives fitfully and imperfectly to exercise a more reasoned control over reflexes that are strongly conditioned by long periods of animal and savage ancestries. Impressed by his increasing mastery over certain of the physical elements in his environment, man feels emboldened to aspire to a self-devised organization and management of human life on this planet. Fortunately stronger than the deliberate purposes of reformers or dictators, however, are the human differences they blindly seek to suppress. For it is by virtue of these differences—resultants of concomitant variables of race, climate, culture, or biological vitality—that nature, through the continuous processes of elimination and substitution, is able to recruit in each age the vanguard of the forward march.

THE ZOOLOGIC DISTRIBUTION OF INTRA-ORAL CANCER

By Dr. HAYES E. MARTIN
ATTENDING SURGEON, MEMORIAL HOSPITAL, NEW YORK CITY
and BEULAH F. HOLLAND
NEW YORK CITY

ALTHOUGH cancer has long been known to occur in practically all species of vertebrates, there has been little scientific interest in animal cancer until recent years. From a purely economic standpoint, little or no importance is attached to the frequency of this disease in animals, but the subject is of considerable significance in a study of the cause of cancer in man.

For the most part, malignant growths in man and in animals appear to be similar under the microscope and to follow about the same clinical course. It would be reasonable, therefore, to assume that they arise from the same cause. On this premise numerous investigations have been carried out in series of animals purposefully subjected to specific cancer-producing agents. It has long been known that certain forms of cancer—as, for instance, cancer of the skin—can be produced in rats and mice by repeated applications of coal tar. Internal cancers can also be produced by the injection of hormones. By careful hereditary selection, cancer-susceptible strains of mice have been developed in which the occurrence of the disease in various forms is very high. While these studies have served to demonstrate the potency of several now well-known causative factors, they have also further disclosed the complexity of the problem as to the essential nature of this disease.

Any discussion of cancer in animals must take into consideration two distinct groups of cases—first, those growths produced experimentally in the laboratory and, second, those arising spontaneously. Each group has its special significance, and no informative conclusions can be drawn from pooling statistics of the two. The study of experimentally produced cancer has been invaluable in the discovery and investigation of special causative factors. For comparative purposes, however, cancer which occurs spontaneously in animals should have a closer relationship to this disease in man and, therefore, should also merit serious consideration.

The general anatomic distribution of animal cancer has been discussed in numerous reports, but we have found in the literature no detailed analysis of this disease with regard to the mouth and throat. The specific purpose of the present study was to determine as accurately as possible from available evidence the topographic distribution of spontaneous cancer of the mouth in animals as compared to man and, furthermore, to correlate any differences in distribution with known variations in the cancer-producing influences to which man and animals, respectively, are subject. We have found in the literature 122 case reports of cancer occurring in the mouths, throats and nasopharynges of animals, and we have also collected 35 cases (not previously reported) by communicating with zoos, veterinary schools and veterinarians throughout the United States and Canada.

TOPOGRAPHIC INCIDENCE

In almost half of the cases reported in the literature, the exact anatomic site of the growth is not clearly designated;

cancer is reported vaguely as having occurred in the "mouth," the "pharynx," or the "nose." Such non-specific anatomic classification is, of course, unsatisfactory and probably indicates that the observer was either unfamiliar with the anatomy of these regions or uncertain as to the exact site of origin of the growth. In human cancer, that which occurs in the tongue has a different significance from the standpoint of treatment and eventual outcome from that which occurs in other regions as, for instance, the tonsil, and therefore in a study of human cancer great care must be taken in determining the precise origin of a tumor.

In Table I are listed the relative percentages of the anatomic forms of intraoral cancer in man and in animals—the latter figures based upon our collected

TABLE I
ANATOMIC DISTRIBUTION OF CANCER OF THE ORAL CAVITY*

	Human beings Per cent.	Animals Per cent.
Lip	29	15
Tongue	27	18
Buccal mucosa (cheek)	10	5
Jaws	10	39
Palate	9	15
Tonsil	8	5
Floor of mouth	7	5

* These percentages for animals were calculated from our collected cases.

series. It will be noted that in this group of animals, cancer of the jaws is the most frequent (39 per cent.) and, so far as the mouth is concerned, appears to occur in animals with about four times the relative frequency as in man (10 per cent.). Tongue cancer (27 per cent. in the human being) makes up only 18 per cent. of the intraoral tumors in animals. However, since it ranks second in frequency in both groups, we see little merit in the emphasis which D'Arcy Power[1] placed on the supposed rarity of cancer of the tongue in animals. The relatively high frequency of lingual cancer in man can be rather definitely attributed to such exclusively human causative factors as syphilis and tobacco, and to chronic inflammation of the tongue from other causes from which the animal is practically exempt. For instance, leucoplakia (white patches) of the mouth, which may be briefly described as a thickening or callous formation of the lining of the mouth as a result of chronic irritation, and which is found to be a precursor of cancer in man, has never (so far as we know) been reported to occur in animals.

[1] D'Arcy Power, "Selected Writings, 1877–1930." Clarendon Press, Oxford, 1931.

It is interesting to speculate as to the reasons for and the causes of the greater relative frequency of cancer of the jaws in animals. Dental defects similar to those of middle or old age in the human being are not common in animals and obviously play only a minor role. It might be possible that the more natural dietary habits of animals tend to spare the teeth but to produce chronic injuries to the soft tissues around the jaws, while the reverse is true in man. The high incidence of tumors of the jaw in animals may also be due, in part, to the frequency of adamantinoma (3 of 12 jaw cases in our series). This tumor arises from the same tissues which develop into the tooth structure in the embryo and not, so far as we know, as the result of any form of chronic irritation. It is very rare in man.

Cancer of the tonsil and of the floor of the mouth, two fairly common sites of origin in the human being, occur in only slightly lower percentages in animals.

HISTOLOGY

We were able to obtain histologic slides in 20 of our collected cases. Dr. Fred Stewart, pathologist at the Memorial Hospital, who examined these slides, states that the tumors are in no way distinguishable under the microscope from human cancer. He diagnosed as squamous cell carcinoma four cases of tongue tumors, three in dogs and a fourth in a horse. Adamantinoma oc-

curred in three of twelve cases of cancer of the jaw (2 dogs and 1 horse). Among the other slides in our collected group Stewart found adenocarcinoma (2 cases in the jaws of horses), epidermoid carcinoma (2 cases in the jaws of dogs, one in the jaw of a horse), melanoma (2 cases in the jaws and 1 in the soft palate of dogs), squamous carcinoma (1 in the jaw, 1 in the soft palate, and 1 in the tonsil of dogs), epithelioma (1 case in the roof of the mouth of a dog), and myxosarcoma (1 case in the jaw of a dog).

Age Incidence

In animals, the age incidence of intraoral cancer as well as of other anatomic forms of this disease follows the same general trend as in the human species. Malignant tumors of any anatomic variety rarely occur in the young. In our collected group of animals with cancer of the mouth, all were adult and many were definitely classed as aged.

Some idea of the general age incidence of cancer in animals may be obtained by reference to the report of Cohrs.[2] In autopsies on 592 dogs below ten years of age, he found ten cases of carcinoma, eight of sarcoma and one of multiple tumors—a cancer incidence of 3 per cent. In autopsies on 145 dogs over ten years of age, he found ten cases of carcinoma, two of sarcoma and twenty-five of multiple tumors—a cancer incidence of 25 per cent. Cramer[3] has pointed out that in certain sections there may at times appear to be an epidemic outbreak of cancer in animals, which on closer analysis could be explained by the fact that an exceptionally large proportion of aged beasts had come under observation.

Species Incidence

It is evident that the apparent or reported frequency of cancer in animals is influenced by many factors; for example, the relative numbers or the population of the different species and their life expectancy under varying wild and domestic conditions. Perhaps more important than either of these is the degree to which any given species is associated with man, since the discovery of cancer in animals requires a certain amount of attention which only domestic or captive animals receive.

It is to be expected, therefore, that the majority of reported cases would be found among those kinds which are most numerous or which, for either practical or sentimental reasons, are considered most valuable to man; namely, the dog, the horse, the cat and the cow. From the standpoint of a fairly complete postmortem examination, the reported incidence in slaughtered animals would probably be high except for the fact that most of them are killed before they reach the cancer age. Trotter[4] reported that although he found 21 cases of cancer in an unstated number of slaughtered aged cows, there were no new growths in 5,300 slaughtered sheep from 6 to 12 months of age.

Using the cat and dog as examples, Dobberstein[5] stated that among domestic animals the carnivorous are more susceptible to cancer than the herbivorous. However, the high incidence of intraoral cancer in the carnivorous cat and dog may be due mainly to the fact that they are permitted to live to advanced ages while the herbivorous cow and sheep are likely to be slaughtered for food before they reach the age at which cancer usually develops. That old age is probably a greater factor than a carnivorous diet is suggested by the fact that the herbivorous horse, which continues to be useful as a beast of burden until old age, is more frequently reported as having cancer than any other animal (Table II).

[2] P. Cohrs, *Cancer Review*, 2: 197, 1927.

[3] W. Cramer, *Cancer Review*, 7: 16, 1932.

[4] A. M. Trotter, *Jour. Comp. Path. and Therap.*, 24: 1, 1911.

[5] J. Dobberstein, *Berliner tierärztliche Woch.*, No. 7, p. 100.

TABLE II
SPECIES INCIDENCE OF CANCER IN ANIMALS

Animal	Upper respiratory and alimentary tract*	Oral cavity alone
Horse	85	33
Dog	43	35
Cat	8	8
Cow	5	3
Trout	3	3
Antelope	2	2
Bear	2	1
Sheep	1	1
Pig	1	1
Hen	1	1
Wolf	1	1
Coati	1	0
Caracal	1	0
Genet	1	0
Raccoon	1	0
Civet cat	1	0
Total	157	89

* Mouth and nasal cavities.

In the mouth itself, about an equal percentage of cases occurs in the horse and in the dog. The cat seems to be particularly susceptible to cancer of the tongue (6 out of 8 cases, or 75 per cent. of the reported cases of intraoral cancer in the cat), in contrast to only about 10 per cent. of lingual cancer in dogs and 4 per cent. in horses. The feline habit (more prominent than in other animals) of preening the fur by licking suggests itself as a possible explanation of this special susceptibility to tongue cancer. In answer to our inquiry, Dr. C. R. Schroeder, of the New York Zoological Society, states that there are many wild animals of the feline family who have the same habitual tendency in this regard, but it is to be noted that no tongue cancers have been reported in any feline except the house cat.

The true incidence of cancer in wild animals is, of course, impossible to determine, but on rather scanty available evidence the reported frequency as compared to domestic animals is low and lends support to the theory that age plays an important role in the development. It is obvious that household pets under normal conditions enjoy unusual longevity. By comparison, the lives of wild animals are short. It is a well-known fact that they usually die violent deaths as soon as their physical powers decline, so that they can no longer defend themselves against their natural predatory enemies nor compete with the younger and more robust members of their own species in the struggle for sustenance. Even without more definite proof, one would be justified in concluding that in general they do not live long enough to reach the cancer age. Moreover, even if cancer did exist, there would rarely be an opportunity to determine and record its presence, whether death is due to natural or to violent causes. It is only in zoos that animals of the wild species are observed closely enough for the accurate recording of the occurrence of cancer. Even in these animals the incidence is probably increased by the change in environment and the extended life expectancy.

It is interesting to speculate whether a seemingly high incidence of intraoral cancer in domestic as compared to wild animals might indicate that new causative factors have been introduced by an artificial or unnatural mode of life. Certainly such animals as cats and dogs under domestic conditions do not follow the same dietary habits as their related wild species, nor are they subjected to the same environmental influences in other respects. Such a theory has also been advanced by Brooks,[6] who was of the opinion that cancer was extremely rare in wild animals living in their native state and that abnormal living conditions undoubtedly increased the incidence of new growths in the common domestic animals. This is interesting as a corollary to the view held by many investigators that cancer in man is a "disease of civilization."

Compared to the change in man's environment from his former primitive to his present civilized condition, the ani-

[6] H. Brooks, *Proc. Soc. Exper. Biol. and Med.*, 3: 39, 1906.

mal's transition from the wild to the captive or domestic state can hardly play a major role in the development of cancer. No matter how domesticated an animal becomes, nor how much his new environment differs from that of his wild life, he is still almost entirely free from certain highly significant cancer-producing influences to which man is subject. For instance, from the standpoint of intraoral cancer, the animal is not exposed to any extraneous irritant similar to tobacco or to alcohol. Furthermore, even under the most artificial conditions the animal's food is usually bland and neither hot nor otherwise irritating, since the average beast would instinctively refuse food which did not conform to its natural diet in these particulars. Moreover, the animal is not subject to any disease competent to produce precancerous changes in the tongue, like chronic syphilitic glossitis in man. A disease called daurine, or horse syphilis, is reported to be common in Africa, but so far as we can learn there is no associated chronic inflammation which might be a precursor of tongue cancer.

In certain respects, the incidence of cancer in animals may closely resemble that in primitive races. It has been frequently noted that in primitive peoples both the incidence of and the death rate from cancer is low. Hoffman[7] reports that among the Maoris of New Zealand the death rate from cancer is only 33.7 as against 112.0 per 100,000 in the United States (1937). Lee and others[8] have reported on the rare occurrence of cancer among American Indians. Comparing these peoples to civilized races, this discrepancy might be due not only to a more primitive and therefore more natural environment, but also to a known shorter life expectancy.

[7] F. L. Hoffman, *Acta Cancrologica*, 1: 279, 1935.

Conclusions

The incidence of cancer of the mouth and throat in animals, although impossible of exact determination, is undoubtedly low as compared to that in man. Such a relatively low frequency may be due to a more natural mode of life and indicate that intraoral cancer in man is mainly due to causative factors which have been introduced by civilization and to which animals are not subject. It is only with advancing civilization and increasing intelligence that the environment of any living thing departs very far from the wild or savage state. Considered in this light, no matter how modified the animal's mode of life becomes, it can never be changed to the same extent that modern civilization has altered the environment of primitive man, from the standpoint of cancer development. It is probable that an extension of the normal span of life is the one important contributing factor to an increased incidence of spontaneous cancer in domesticated animals, and that this incidence would be higher if these animals were all permitted to live to an age comparable to the average life of man.

[8] B. J. Lee, *Surg., Gynec. and Obst.*, 50: 196, 1930.

LOOKING FOR AN HONEST MAN

By Professor A. A. LEWIS
DENISON UNIVERSITY

DIOGENES is back again with his lantern. But this time the lantern looks too much like a laboratory to be regarded as a trick of burlesque employed to incite an insurrection against dishonesty. The new Diogenes is acting on the assumption that humanity is, finally, in the mood for a G-Man diagnosis and he is, therefore, coming on the scene with a lantern that will actually pierce the surface of outward demeanor, however pharisaical, and show a man up for what he is. Deceit is to be revealed, as it were, in terms of candle-power notches.

It is not a false assumption that mankind has begun to worry about its behavior and is, accordingly, quite ready for this follow-up appearance of Diogenes. We are to-day, from the least sophisticated to the most, very ready to accept the implication that honesty can be so scarce and be so cleverly counterfeited that more than ordinary daylight is required to discover it or penetrate a substitute pretension. We have come to believe that a mission in search of an honest man is an important one, as important even as a mission in search of an intelligent one. Our intellectual vanity has been forced to concede that there are other personality traits besides intellect which make a difference, and among them is moral caliber.

It has been a long time since Diogenes conducted his one-man parade along the streets of Athens in protest against the failure to stress the keystone significance of character in human behavior. Taken to heart by contemporaries and successors, the old non-conformist's broad hint should have brought about considerable reformation during the intervening stretch of centuries. A geologic period in which to mend its ways, and yet human conduct continues about as badly rent as ever. Little more has been done than to win a theoretical acceptance of the great value of moral integrity: noble ideas, apparently, compensating for ignoble living. And reference to unconverted human action is not limited to professional offenders; the unscrupulous swindlers who give fine bargains in bogus stocks and the wily criminals, of a thousand specialties, who dupe their victims with unprecedented finesse. The ordinary man, the law-abiding citizen thought to be well above board in his public and private actions, is not too good to resort to fraud on occasion. He may not be a professional, but in a pinch he can play the game pretty well as an amateur. Certainly that man is well above the honesty-average who does not consider it an advantage, frequently, to hide behind a screen of deceit and would not, if he had to step out and reveal the facts, feel like a nudist—a nudist with blemishes. Among these offenders against honesty is the common gossip, whose name is legion, the rumor-monger who may go so far as to aid in a whispering campaign to defame, the radio huckster whose blatant exaggeration has only the sky as the limit, the money grabber who signs his famous name to an unqualified indorsement of cigarettes he has never smoked, and last but not least, the political chameleon whose principle changes color with every shift in vote-getting expediency.

It is not to be assumed that in all the generations since Diogenes no attempt has been made to solve our moral problems. It is true only that the solutions have stopped with kings' charters giving

claim to remote regions; have stopped with vague theory and cloistral speculation. So that the remark, "What personality is everybody knows but nobody will tell," is practically as true of character as it is of personality. Through all these long centuries the thing needed to make the theorizing about morals more than mere speculative pastime has been a survey of actual behavior. But it is just recently that students in this field have come to realize—certainly to show by their actions—that nothing short of a measuring scale for morality is going to bring ethical theory out of the clouds and answer such practical questions as: How far is it possible to teach morals? Or, What schemes now existing or to be proposed for producing the "cardinal virtues" are to be preferred? And those questions about the effect of the environment, or other concomitant factors, namely: What effect, for example, does "company kept" have on one's conduct, or does health or mental level?

Looking for an honest man—a quest which on account of the rarity of spontaneous specimens will, of course, turn out to be mainly a question of figuring how to produce one—has, then, come to be recognized as a venture which needs the cooperative labor of the objective investigator. Further, with respect to the steps in the search, it is clear that the first worry will have to be, not the discovery (or production) of an honest man, though that is the end-goal, but the discovery of an improved lantern. Rays must be found which will penetrate deeper into the darkness, whether it is a matter of finding guilt after an offense has been committed or of finding guilt ahead of time in terms of degree of moral liability or, inversely, in terms of amount of capacity to go straight in the face of temptation. Finding the offender is apt to be too much like making an inference that the child with a jelly ring around his mouth is guilty of robbing the pantry, though while he was innocently napping the ring may have been transferred there, so to speak, from the face of the actual culprit. And only the faker still claims that the lines of the palm, the cut of the countenance, the contour of the cranium and the revelations of the horoscope give a trustworthy tip on future conduct. A technique is needed which will locate guilt and establish an index of moral dependability with less beating around the bush by circumstantial evidence and with none of the discredited fortune teller's art. What promise is there that our patient and ingenious modern Diogenes, with his deceit-measuring inventiveness, is going to subject guesswork and trickery to much of a purge?

The ambition to apply the yardstick to morals was given its initial boom by the so-called "lie detectors"—the word-association trap which the victim snaps by his own response to verbal bait—and the laboratory instruments for securing telltale breathing curves, blood pressure records and galvanic-reflex readings. The operation of the first of these "lie detectors" is illustrated by the city youth who a few years ago arrived in Toronto, Canada, claiming to be a half-civilized bush boy who had been robbed of furs on the northern border, and then pricked the bubble of his clever romancing by replying with "Dempsey" to the word "fighter," suddenly shot at him, and with "first" to the word "safety," and by taking a longer time to reply to incriminating than to neutral words when he tried to hedge. The operation of the other detectors—if they had been used in this instance—is easy to picture: the rubber girdle about the boy's chest, the pneumatic sleeve wrapped around his arm, and the electrodes of the galvanometer in contact with his skin—all counting as so many additional triggers to set off the trap.

For the most part these "mind reading" devices have been employed for demonstration purposes in the psychological laboratory, where they have been kept (or returned) for further study and

improvement. In the early days when the word response was the only trigger the trap had, few people rated its reliability very high and hardly anybody besides Hugo Münsterberg took stock in the opinion that this new-fangled method of snaring the evil-doer should be substituted for that crude and inhuman method of "working on" suspected criminals, known as the "third degree." But with the multiplication and betterment of these psychological devices and their use in combination, the faith of the few has spread, and it is becoming not unusual to read in newspaper and magazine that the "lie detectors" have been given again—given upon invitation and for practical reasons, let it be added, and not under sufferance to please the whim of some insistent experimenter.

But it is well that popular favor has given its patronage to the "lie detectors" an inch at a time. These detective instruments, like an x-ray machine, may turn culprit or criminal inside out, as by zigzagging curves and dial readings his deeper bodily changes are made visible, but it still remains to interpret the picture. The suspect's guilt or innocence is not spelled out in unmistakable letters. The fact that these deeper, organic reactions are involuntary and can't be made to belie culpability like a face "kept straight," does not guarantee that they can be subject to no other source of causation except actual misconduct. How much more simple the laboratory detective's assignment would be if only, as the Hindus thought, a person moved his big toe every time he lied, and still more assuringly than the Hindu legend mentions, moved it at that time and no other! But the symptomatic correlate of deceit has not turned out to be so easily recognizable or so unambiguous in its significance, and the locating of guilt, even where the offense is large, is requiring all the resource that scientific specialization can command.

It is not claimed, even by the psychological sleuths, themselves, that this new technique makes the detective's art infallible. When asked to give the "lie detector" test to a person suspected of murder, of kidnapping, of embezzlement, of fraternity thieving, of having injured a pedestrian or any of a thousand major or minor offenses, our humane inquisitors feel unhesitatingly certain of their findings only where confession follows. But this dependence on confession for 100 per cent. reliability is not to be taken as an admission of zero futility where confession does not follow. Psychological sleuthing is not purely a matter of running a bluff.

The fact that "70 per cent. of the offenders confess" when put through the test ordeal would indicate that the guilty individual is routed out of almost his last hiding place. Certainly as compared with the medieval ordeal of having to swallow rice flour, the modern stratagem is an enormous improvement. Though what is sought is still a telltale fear reaction, the dryness of the mouth, as indicated by the state of the chewed rice or the ability of the suspect to swallow the morsel without choking, did not give as trustworthy a clew as does the fear-caused moisture of the skin as indicated by the easily deflected needle of the galvanometer; and this advantage in trustworthiness is more than tripled when circulatory and breathing changes are added. The gain in dependability comes not only from more accurate ways of measuring incriminating responses but also from more artful ways of keeping accused innocence from making such responses, at least from making them with anything but negligible infrequency. If a "dry mouth" is about as apt to convict the guiltless as the guilty, then the same might be expected to be true of a moist skin, for the salivary glands and the sweat glands are about equally beyond the control of the individual under suspicion and about equally sensitive to emotional excitation. There is something to be said for a trap which is so delicately poised that it will be sprung by the cool-

est criminal, but only if it can't be sprung by the excited innocent. In order to escape such a fiasco of justice, our modern Sherlock Holmes has attempted, therefore, to keep the guiltless from knowing when excitement will mean guilt and to make enough "inside" references to the crime to allow two or three doubtful responses on the part of the falsely accused to pass as accidental. The stimulus words with which the suspect is confronted are selected with a painstaking ambition to make sure that sprinkled among "non-crucial" words there will be "crucial" words, the kind that only the actual perpetrator will consciously connect with the crime or misdemeanor. The word "shovel," for example, used as a "crucial" word to catch the slayer of a dog, is no part of a trap to any one except the person who took the animal's life by means of such a weapon, unless publicity has already made such knowledge common property, and this would hardly be true of the majority of the trigger words. Only for him does the word "shovel" disturbingly suggest the immediately-tabooed response "dog," and excite questionable skin reflexes (and breathing and blood-pressure changes). That is to say, a trap that is tremulously sensitive to fear is set only for the fellow who knows too much of what went on behind the scenes, and the guarantee that the jaws have clamped on a law-breaker is in direct proportion to the amount of disagreement between the responses to incriminating words and the responses to neutral words.

Likely, enough has been said to show that the "lie detecting" strategy is competent to afford some help in the quest for an honest man. Old Diogenes would have swapped his lantern for such an improved technique and would have gloated over an opportunity to try it out on some of those popular ringleaders whose deception stirred his cynicism. But if he had wanted to use the "lie detectors" to prevent crookedness rather than to catch the crooks, he would have found their utility limited in two disappointing ways. For one thing, they are not as competent to discover the non-delinquent, or pre-delinquent, child, as they are to discover the delinquent youth, or criminal adult. And for another thing, they have only a snail's competence for accumulating data on a large sampling of individuals. Only searchlights which can be turned on a group of individuals, all at once, will supply the abundance of data needed to catch a thief, a liar or a cheater, ahead of time; make it possible, that is, to know to what degree a group (or less certainly, an individual) is potentially dishonest. But the "lie detector" method is not alone in the search for an honest man. Two other methods, the biographical and the statistical, have joined in the hunt and are attempting to provide the resources needed to discover the wayward while dishonesty is at a minimum and honesty at a maximum and while it is possible to start the wayward one on the right track without having to back him up so far.

The biographical method of looking for an honest man, reckoned from the time it got its name (especially if one designates it by the name, "biometrical"), is a relatively young sort of strategy. It has been only a few decades since we began reading about the "juvenile court," the "visiting teacher," "family case-work" and the "child clinic." But in terms of its essential nature, the method dates back to the first attempt to handle a troublesome child by getting better acquainted with him and not by "beating" him.

The short-cut of the laboratory magician with his lie-detecting set-up (his polygraph which registers its several findings simultaneously) is at the other pole from the procedure which characterizes the biographical technique. The tactic here is that of the clearing house to which a group of banks with overlapping obligations send their accumulated checks for comparison to find out

what the actual disparities are; only in this case the checks are diagnostic items which range from the pick-up of casual observation to the data which is obtained under strictest control. In order to discover and clear up any "trouble spots" where character fails to balance, all sorts of diagnostic ingenuities are laid in command, not excepting the "lie detectors." Actuated by the stimulus of a reclamatory goal, which alone can prevent the assembling of facts from becoming a Dead Sea of routine, the field investigator, the psychologist, the physician, the educational expert and the juvenile court judge may all combine to play the rôle of "Good Samaritan" to the neglected youngster who has been beaten by cruel circumstance and left maladjusted by the wayside; and no effort is spared to learn what such a child needs to have done for him so that he may be cured of his injuries, and through follow-up oversight stay cured. In gathering information for treatment and guidance, many a stone of personal and familial history is turned; sometimes the investigative ramifications are so varied and exhaustive as to be amazing. It is reducing the account of one of these elaborate samples from ninety pages to nine lines to say that practically everybody was interviewed, every written item which might contain a bit of pertinent fact scrutinized, and every resource of science called on for aid. What the parents and other relatives—even neighbors—could contribute was tactfully elicited; school records, including teachers' opinions, and health records, both mental and physical, and for parents and grandparents and other near relatives as well as for the child, himself, were conscientiously sought; and numerous blanks were filled with the data obtained by physical, psychological and psychiatrical examinations. And, of course, a clinical inventory could not be considered exhaustive unless it included the youngster's autobiography, the inside facts, usually gained through friendly and informal conversation, but sometimes supplemented by the more formal maneuvering of the psychoanalyst.

Imagine some distinguished personage submitting to a biographical overhauling so revealing and authentic! Only a Rousseau or a De Quincey—two in a million—would permit so much truth to be brought to light. Needless to say, such an unrestricted inventory is rare even in a clinical biography; though this is not because the loss of reputation is greatly at stake. A clinical diagnosis, in contrast to a "debunking" biography, is kept as private as possible and not advertised to the four winds. The expense is the rub; it is too great for charity to carry, and the general public is not yet willing to bear the burden through social security taxation. Yet, however infrequent this elaborate case study, it serves to show how far biographical lantern-bearing is competent to throw light on the classification of children according to character, and to acquire, thereby, the wisdom necessary to guide in the rebuilding of weak places.

It is unquestionably true that, by acting on the proposition which holds the restoration of the offender to be more important than the figuring out of a penalty commensurate with the offense, the biographical method has been able, through reducing dishonesty, to supplement the purely negative "lie detecting" method of looking for an honest man. But still there is room, after the laboratory detectives and the clinical biographers have done their utmost, for some Diogenes to be skeptical about our being able either to find or produce an honest man. The detective machinery can, at best, do little more than make the gross distinction—guilty or not guilty; and the biographical cross-checking procedure can do little more than make gross qualitative contradistinctions, than classify a particular problem youngster as a first-time offender or a repeater, or as a normal delinquent or a constitutionally psychopathic one. Furthermore, each artifice—especially the first—is open to

the criticism of having arrived after the thieving (lying or cheating), in such amounts as to shock society, has already occurred; and it follows, of course, that each artifice has the limitation of not being able to check with any nicety on how much progress is being made—or can be made—through any reclamatory program.

But it would seem that in this matter of finding an honest man, invention is not going to stop short of a thoroughgoing attempt at discovery; for a third method, the statistical, has joined in the search and is undertaking, specifically, to remove those last doubts of skepticism. This method, which aims to get data on more and more individuals (mainly school children) and keep it up until the data are inclusive enough to make possible the discovery of authentic measuring devices, is, just now, in the thick of a struggle against the necessity of treating honesty merely as a qualitative fact (as hedonistic ethics through long centuries has had to treat happiness and pain and continually fail to obtain their algebraic sum). It would reduce trustworthiness (or untrustworthiness) to quantitative units, and do it with a measuring scale whose subdivisions are sufficiently small to give a reading on delinquency while still in the pre-delinquency stage; to furnish a criterion for reckoning with some exactness, and ahead of time, the amount of moral vulnerability (or resistance to temptation); and to appraise with practical dependability both the relative merit of different character-education schemes and the comparative potency of such concomitant factors as intelligence, physical vitality, cultural background, school achievement, company kept, home conditions, and so forth.

To provide for the measuring of capricious character a scale of such instrumental dependability and wide serviceableness is an accomplishment which only the future can guarantee. The fractional results secured in the parallel task of measuring intelligence, though sufficient to embolden with some confidence, have not failed to teach prophecy to be modest when it comes to the question of measuring something which is not only difficult to define, but difficult to isolate—to tease out of the behavior tangle—however ingenious the technique employed. Our investigators of character are confronted with the same question which has confronted the students of intelligence, namely: "How translate a vague intangible into objectively computable conduct, and by so doing bring it under predictive control?" Which in this case means, "How prevent dynamic nature from running wild in delinquency and crime?" And the answer, again, is: "Do it by running the individual through a gauntlet of standardized situations, called tests, and then calculating the score by means of statistical devices."

The requirement laid upon any measuring instrument that it have a base line from which to make its quantitative calculations and that it have its subdividing notches identical throughout the instrument's range, are hard exactions for any "mental testing" scheme to satisfy, and character testing in its own way must pass through these fires.

Locating a zero point for deception is analogous to doing the same thing for handwriting, and in the instance of one scale of penmanship specimens, the specimen which is just illegible takes the base line position. A rather fuzzy line, but better than none; and this double declaration holds for the base lines so far figured out for the various tests being used, cooperatively, to grade character; they too are in the rough, but they are a move in the direction of a precision that is better than saying, for example, that the zero for morals is the dividing line between being in and being out of the penitentiary. It is safe to consider it an improvement upon the old dichotomous classification which says that an

adult or a child can either be trusted 100 per cent., or can't be trusted at all, and consigns all deception, of whatever degree, to the same diagnostic black hole.

Least elaborated are the statistical attempts to make a quantitative diagnosis of stealing and lying. In the matter of theft, "coins" have been substituted for the "pepper-filled cherries" of the old McGuffey Reader. The merchant, there told about, would have come nearer to finding an honest boy to serve as clerk, if he had placed money instead of cherries on the table in the waiting room. Money has the advantage of providing about the same degree of temptation to every prospective sucker. One youngster may crave some particular article more than another, indeed may not have the least craving for cherries; but a nickel is no particular article, it is five cents worth of whatever is most dear to the heart.

In the matter of lying, the dishonest are caught by an assortment of questions which relate to behavior standards and tempt the interrogated to angelic pretensions. "Do you always keep every secret that you promise to keep?" is one question. "Did you ever write your name in the books you use which belong to the school or library?" "Do you always congratulate your opponents?" "Did you ever hurt or cause pain to a dog, cat or other animal?" "Did you ever blame another for something you had done when you knew all the time it was your fault?" "Did you ever take anything (even a pin or a button) that belonged to some one else?" These are other questions; and there are still others, enough altogether to make any one but a "pious fraud" acknowledge some shortcoming.

In the check-up on thieving or falsifying, the character-testing technique is close to the starting point in its development into a measuring scale. In the coin-tempting set-up the tempted individual either steals one, or more, of the coins, which he has an apparently safe opportunity to steal, or he does not. Having provided a lure and a promise of escape that closely duplicate life's own realism, the tester needs only to look at the scale-beam, as it were, and take the readings, in order to know whether the tempted one is guilty or not, and in order to have a basis for predicting future conduct—a past on which to base an index of (some) trustworthiness. Also, in its relatively undeveloped strategy, cornering a falsifier does not involve a great amount of statistical juggling.

It will, therefore, be advantageous to shift our story before going deeper into the statistical technique, since it is in connection with cheating that the attempt to find a borderline between honesty and dishonesty, and a dependable scale unit to measure distance from this line, has carried the maneuvering to greatest lengths.

To find a zero point from which cheating can be calculated it has been necessary to find the average score of a group of individuals in a standardized performance and, then, to correct the middle score by making an allowance for legitimate fluctuations. The size of the correction is the average of the "gains and losses" of the same participants in a second undertaking which, in difficulty, is a twin of the first. This procedure has the sanction of everyday observation. A group of golfers, for example, playing a standardized course to-day and a different, but equally difficult, course to-morrow, would hardly be accused of cheating if the average for the second set of scores differed somewhat from the average for the first set. Cheating can be counted only from the point where chance fluctuation ends.

If when unsupervised, an individual's score rises above the level of legitimate upward fluctuation from the corrected middle score, by so much is it made probable that the score is too good to be true. And if this rise in fluctuation is as much as three sigmas above the honest-average

fluctuation of a large enough random selection of individuals to give a surface scatter of scores comparable to the side-view of an admiral's hat, the probability that cheating has occurred is about 999 in 1,000. This estimate is based on the fact that in a normal distribution of scores a scatter of six sigmas—three on either side of the central score—wipes up 99.73 per cent. of the cases and reduces the chance of occurrence for a deviate of 3 sigmas to 1.17 in 1,000. From these figures it would appear that one would have to be a terrible sinner to be caught, but this is true only where the calculation is based on a one-test temptation. With a considerable number of tests all pointing a finger at an offender much smaller single probabilities will convict. It would take a whale of a drop in a golf score to give "hanging certainty" of dishonesty, but were there probability of cheating in business, in lodge affairs, etc., as well as in golf, much smaller amounts of probability would give highly reliable grounds for the assessment of guilt.

We are not forgetting, of course, that dishonesty is not satisfactorily measured until its probability is calculated with respect, not only to the past, but also to the future. It is important to know the degree of probability that an individual has committed an offense, but it is equally important to know what are the probabilities that he will repeat if he gets a chance, if he faces a similar temptation.

The amount of certainty with respect to the eventualities connected with any particular individual is less, as is generally known, than the amount of certainty with respect to the group. A life insurance company can base its financial security on a group life-continuance probability which guarantees nothing about the longevity of any single member of the group. Very little trespassing by our golfers as a group, beyond the limit permitted by honest fluctuation, would suffice to guarantee not only that cheating had been committed but that—without the intervention of some Billy Sunday—it would occur again under similar circumstances and in about the same amount.

Character tests, competent to check on the group as a whole, will make it possible to calculate the comparative effectiveness of Scout participation and Sunday-school attendance, of instruction which points a moral and instruction which lets noble conduct speak for itself; to calculate the anti- and pro-moral influences of slum and select communities, of broken and intact homes, of bad and good companions; and to calculate—as intelligence testing now does in its field—how well certain types of future stresses are going to be withstood, to know ahead of time the morality risk. But if the statistical maneuvering is going to be competent to measure with any such trustworthiness the effects of training and circumstance on the conduct of a particular member of the group, the tests used will have to be greatly refined and multiplied: an accomplishment which will require a "vast amount of work" and an abundance of inventive genius.

In endeavoring to measure honesty in school children (the investigator's most accessible subjects) the procedure duplicates to a striking degree the earlier attempts to get a line on such a simple ability as spelling; and in the later endeavor the object is, again, to know when and how much—if any—progress is being made in school and to grade the methods and devices in vogue, or proposed, for educative promise. It is in the scaling of ability to be honest, just as it has been in the scaling of ability to spell, a question of finding hurdles that in smallest number will provide a basis for rating: a question of collecting a list of more and less difficult words from among those most frequently used, in the one case; and of "collecting a list of situations in which deceptive behavior is more (and less) frequently practiced," in the other. The tempting situations are realis-

tic samplings from school, home, playground and party: such temptations as are provided by an opportunity to go against instructions and get help on home work, to use a key not only for grading a standardized arithmetic test but for slipping in a few corrections, to add to a performance in a speed test by writing answers after time has been called, to reach the floor and give weak arms a little help in chinning the bar, and to peep when making the turns in a pencil maze or when pinning the tail on the donkey.

There are around thirty such baiting situations, already contrived, and in connection with each situation some one of a half-dozen different traps is set; traps, called "techniques," and of such camouflaging merit, when ideally constructed, that they can be used again and again with the same children. The deceiver walks into the trap, is caught and is checked on for guilt without waking to the fact that his morals have been scientifically scrutinized. The child who thinks he has improved his showing when he uses a key to doctor his performance on an achievement test is living in a fool's paradise, because the "duplicating technique," by paraffine impression or some similar method, has provided a double of the bona-fide answers. And in like manner the "overstatement technique" works behind the scenes to trap the young pretender who sanctions inflated estimates of his accomplishments by answering "Yes" to such questions as: "Did you receive 95 on your last examination?" "Did you chin the bar 20 times without stopping?" "Did you do your homework without aid from any one?" Then there is the "improbable achievement technique"—to mention a third pitfall. It snares the unsuspecting by setting tasks that, under the rules to be followed in their execution, are well beyond normal human capacity. It is this trap which catches the fakers who with eyes closed thread mazes of such difficulty as to belie the visual handicap; or in the five minutes allowed, perform the improbable feat of clearing a "peg solitaire board," checker-jumping fashion, of all but one of its thirty-three pegs.

At present these baiting situations are too few and the trap-setting too amateurish to provide a very reliable scale for grading honesty. But through the statistical study of character, science is going to provide our modern Diogenes with a third lantern of very piercing rays. And then equipped, not with one but three lanterns, his quest along the streets of to-day should not be doomed to complete disappointment. Not that he should expect to find a perfectly honest man—for sanctified citizens exist only in ideal realms; but such honesty as there is he might expect to find, mixed in each individual instance with more or less dishonesty. Through the instrumentality of the lie-detector lantern, he should be able to find those in whom the alloy of dishonesty exists in rather gross amounts; through the instrumentality of the biographical lantern, whose rays are partly of the ultra-violet sort, he should be able to bring the youthful delinquent into view before he has fallen into the clutches of the belated policeman or the plain-clothes detective; and through the instrumentality of the statistical lantern, whose brightness reveals dishonesty in smaller and smaller subdivisions, he should be increasingly able to guide education in the more ideal task of preventing dishonesty.

In very wishful spirit, we hope that the multiplying successors of Diogenes will keep looking for that "honest man" and that their looking will lead to the discovery of a way to teach morals just as surely as arithmetic is taught, a way to stock this pestilential world so full of honest men that one can be found for every office.

BOOKS ON SCIENCE FOR LAYMEN

A WAY TO UTOPIA[1]

THIS almost encyclopedic volume by one of Great Britain's able young scientists is on a subject of wide interest throughout both the democracies and the totalitarian countries to-day. Perhaps no one is better qualified than Bernal to write such a book, for he has a wide knowledge of science, the vigor and daring—and also the hopefulness—of youth, a zealous interest in the subject and a clear and vigorous style. Yet in reading his censure and his praise we should remember that his youth was darkened by the tragedies that fell on nearly every British family during the World War, his early manhood was disturbed by the severe readjustments that were necessary in the following decade, and during the past ten years he has seen almost world-wide economic dislocations and now the menace of a new war. We are affected by our environment, sometimes profoundly.

The book consists of two parts, "What Science Does" and "What Science Could Do." Of these two parts, the former is the more interesting and probably the more important, although the latter contains many penetrating suggestions, as well as some that enter on the fantastic —such, for example, as diverting ocean currents and developing interplanetary navigation to escape final destruction of the human race.

In the introductory chapter we find, "The new methods of production which science has brought into being lead to unemployment and glut without serving to relieve the poverty and want which are as widespread in the world as ever before. At the same time, the weapons devised by the application of science have made warfare a far more immediate and more terrible risk, and have diminished almost to vanishing point that personal security which was one of the chief triumphs of civilization. . . . War, financial chaos, voluntary destruction of goods which millions need, general undernourishment, and the fear of still other wars more terrible than any before in history, are the pictures which must be drawn to-day of the fruits of science." Even in the disturbed days of the past decade such words could be written only by one whose experience did not extend far back and who ignored the starvations, the pestilences, the wars, the cruelties that have blackened nearly every page of history. This tendency of the author to use in his comparisons some undefined ideal instead of historical realities is characteristic of the crusading spirit. Yet many of his barbed shafts have reached legitimate targets. With excellent aim he shoots his arrows at the weaknesses of the teaching of science in both secondary schools and colleges, at the defects of its uses in industry and government, at the lack of coordination of science, at industrial competition, at monopoly and at many other things which are short of perfection. These criticisms are not simply striking comments about imperfections, but are thoughtful opinions, often supported by evidence, on questions deserving careful attention.

In the chapter on "International Science," which contains a brief survey of science throughout the world, the attitude of the totalitarian countries toward science is very severely, and on the whole justly, dealt with. Indeed, Fascism and the Nazi form of it are unsparingly condemned both as basic theories and in practice. He quotes Herr Dr. Stark's remarkable article in *Nature* and in "Das schwarze Korps," and numerous excerpts from Chancellor Hitler's "Mein Kampf." There is no kind word for Germany or the Germans of to-day, al-

[1] *The Social Function of Science.* By J. D. Bernal. Illustrated. xvi + 482 pp. $3.50. Macmillan Company.

though the Germans are actually a great people who undoubtedly in the not distant future will again join with all other peoples in promoting the science and civilization of the world.

After reading Bernal's strictures on Fascist Italy and Nazi Germany, one is not prepared for his unvarying enthusiasm for the Soviet Union. Over and over again he speaks of the Soviets with warm approval and without a word of criticism. He exalts the words of Marx, Engels and Lenin respecting the organization and use of science. On page 222 we read: "For the last twenty years the prevailing social system has not been universal. There has existed in the world a country in which the basic method of production and social relations have been quite different and consequently the relations of science to society have been so too. The Soviet Union differs from all previous civilizations in having been to a large extent thought out beforehand and in being man's first conscious effort to mould the very framework of his own activities. The basis of these conceptions lay in the criticisms of developing capitalism which was carried out over the last hundred years by Marx, Engels, and Lenin." These strong words about the Soviet program having been thought out beforehand are partly contradicted by (p. 226): "The organization of Soviet Science is somewhat complex and is by no means yet fixed. In the early stages many inprovisations were made, some of which have been retained and others dropped." But this is about the only admission that the feet of the Soviets are partly of clay.

The uncompromising partisanship of the book, emphasized over and over again in many paragraphs, gives the reader an uneasiness that he would not otherwise have. The Russians are undoubtedly a great people who are destined to contribute much to the progress of the world. But they have not yet reached Utopia, even in science, as Professor Edwin G. Conklin learned when he found that his book, "Heredity and Environment," translated with his permission by a Russian into Russian, in 1935, had certain paragraphs and even entire chapters omitted, without notice to the reader that they had been omitted, because they did not agree with Soviet ideology. Such an occurrence takes much of the weight from Bernal's boast of the number of scientific books that have been translated into Russian. More recently there have been several occurrences that indicate that the science of heredity, as it has developed under the influence of the Mendelian law, is not in favor with the rulers of Russia. The International Congress on Genetics, which was to have been held in Moscow last summer, was suddenly cancelled by the Soviet authorities. Still more recently the work of Professor Vavilov, one of the best students of heredity in Europe, has been condemned and, according to reports, "Mendelism and Morganism have been denounced because they do not accord with the principles of our Government."

Probably quite unconsciously, the author falls into an attitude common to the people of all totalitarian states and which appears to be becoming acceptable in this country. That attitude is that an end which appears to be desirable to those in power justifies force to secure it. This idea lies back of all emphasis of the supreme importance in science of organization, cooperation, avoidance of waste, production purely for social purposes and not for profit and similar high ideals set forth in many pages. As I said, I think it was not realized by the author that these ends can be attained in the near future only by a political organization willing to employ force. In fact, he speaks often of the desirability of freedom in science. But uniformity in science and other intellectual pursuits would be more difficult to attain than uniformity in matters pertaining to the body. As desirable as it might be from some points of view, I doubt that the

author would seriously advocate in the interests of efficiency and economy the adoption of a uniform diet designed only to provide the necessary nourishment or that clothing or dwellings should be standardized for similar reasons. It would be easier to secure conformity in these things than in some of those he advocates. The history of life on the earth, and of the advancement of civilization as well, proves the fact that progress is gradually achieved by enormous diversity with many failures, as well as a few successes, and that uniformities lead to stagnation and often to extinction. There is no evidence that man has yet developed mentally to the point at which he can safely avoid diversity and abandon the methods of almost reckless experimentation. I am confident the the author would agree with these sentiments, though many of the things he advocates seem to imply the opposite.

F. R. M.

FOOD FROM THE WILD[1]

For over thirty years Professor Medsger, a gifted naturalist and inspiring teacher of nature study, has been collecting data on the wild plants of North America which yield food for man; and now that he has retired from active teaching, he has fortunately been able to publish the results of his studies in the excellent book before us. The work is divided into sections dealing successively with fruits, nuts, seeds and seedpods, salads, roots and tubers, beverage and flavoring plants, sugars and gums and mushrooms. Under each, the species are arranged in the order followed in standard works on botany, the international system of nomenclature being followed. Under the individual species there are given full descriptions of the plant, data as to its geographic range and notes on the edible parts and how to use them, based in numerous instances on the author's own wide experiences. The text is liberally interspersed with bits of poetry, quotations from early writers on the foods of the Indians and similar material. At the end there are given useful tabulations of the species included, arranged in four geographic categories—northeastern, southern, midland and western. Finally, there is a general index nearly nineteen pages in length.

Many of the food plants included are of course familiar to every one who hikes in the woods, but some of them are rarely if ever recognized as edible. Skunk cabbage, when boiled thoroughly, with two or three changes of water, and then seasoned, is recommended as having a pleasing taste. Common milkweed, when well cooked, is described as much like spinach. Chickweed, "when properly prepared, makes a splendid potherb. I have tasted its edible qualities, and can recommend the plant."

That there are elements of danger in eating some wild plants is clearly recognized. The author points out that it is not desirable to eat many Canada yew berries at one time, and the seeds should not be chewed nor swallowed. He gives a graphic description of the severe colic he suffered when, as a lad of eight, he ate all the May-apples he could. Labrador-tea he finds to make an agreeable beverage, but advises against drinking more than a cup at a time because of its narcotic effects.

Every one who camps out in the woods and who knows enough about botany to identify the commoner plants will certainly wish to make use of this book to aid him in supplementing a monotonous diet of canned goods with native novelties.

Edgar T. Wherry

[1] *Edible Wild Plants.* By O. P. Medsger. Illustrated. xv + 323 pp. $3.50. Macmillan Company.

WHAT IS DOWN BELOW[1]

This volume, one of the series on various physical properties of the earth pub-

[1] *Internal Constitution of the Earth.* Edited by Beno Gutenberg. Illustrated. ix + 413 pp. $5.00. McGraw-Hill Book Company.

lished under the auspices of the National Research Council, is not a light book for casual reading during a vacation. On the contrary, it undertakes to set forth for specialists, and with no attempt at avoiding technical terms, what has been learned about the constitution of the interior of the earth. The subject is very complex and presents serious difficulties and uncertainties in conclusions, as is indicated in the preface: "There remain only those irreducible disagreements which are inevitable with reference to a subject that combines the results of so many divergent and highly active fields of investigation."

After an introductive chapter by the editor, Harold Jeffreys, of Cambridge, England, discusses the origin of the solar system, forgetting, however, the twenty years he held to the Laplacian theory after it had been abandoned in this country, and an equal interval in which he clung to the fission theory of Sir George Darwin of the origin of the moon from the earth. Nevertheless, he has written an excellent summary of the subject assigned to him.

Reginald A. Daly, of Harvard University, follows with a chapter on the inferences that may be drawn from geology. Then L. H. Adams, director of the Geophysical Laboratory of the Carnegie Institution of Washington, contributes a chapter on the elastic properties of the materials of the earth's crust. The closely related subject of the relation of the earth's crust to its interior is treated by H. S. Washington, also of the Geophysical Laboratory. C. E. Van Orstrand, of the U. S. Geological Survey, discusses the observed temperatures in the earth's crust, followed by a chapter on the cooling of the earth and the temperature of the interior of the earth, by B. Gutenberg, and two additional chapters by the same author on the forces in the earth's crust and on hypothesis respecting the development of the earth's crust.

J. B. Macelwane, of St. Louis University, contributes a chapter on conclusions respecting the interior of the earth from earthquake waves, after which he continues with conclusions from deep-focus earthquakes. The remaining chapters are by the same author, with the exception of one on the density, gravity, pressure and ellipticity in the interior of the earth, by Walter D. Lambert, of the U. S. Coast and Geodetic Survey.

F. R. M.

ACCENT ON ODDITY[1]

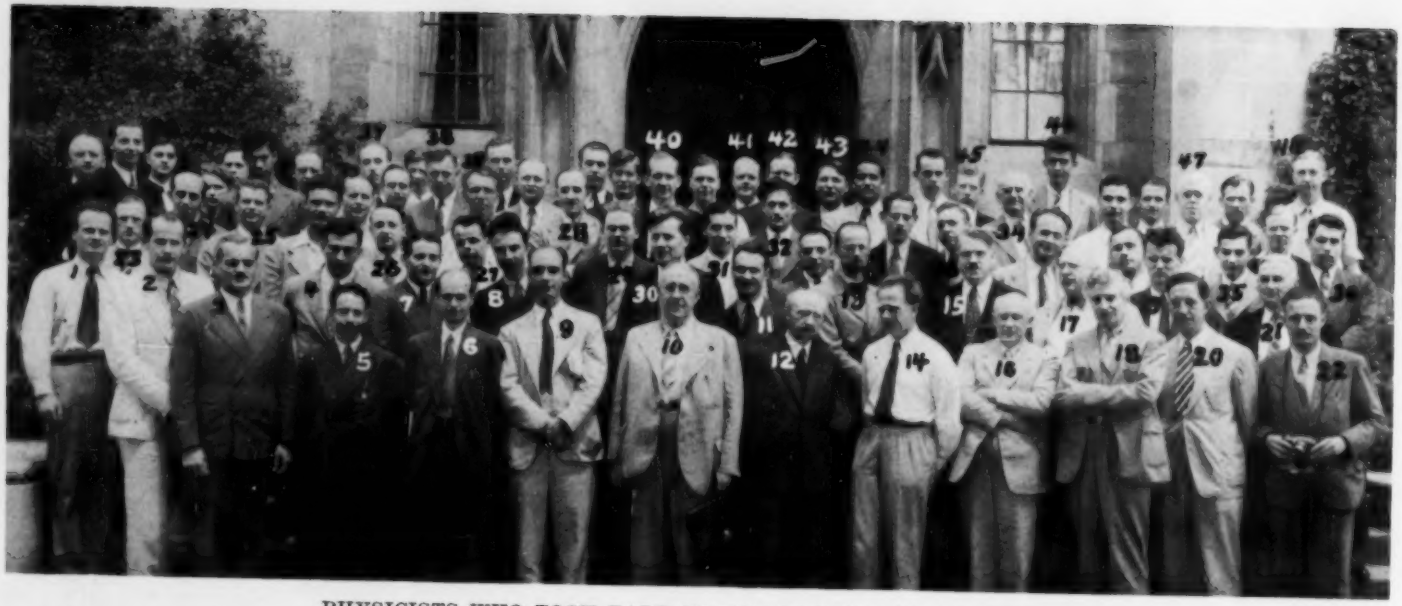
THREE centuries ago, reputable authors described fishes with monks' heads, unicorns and tritons that played tricks on fishermen. Those fictitious monsters have lost scientific standing, only to be replaced by an array of actual animals which seem almost as grotesque and surprising.

To these living "unbelievables" of the zoologic world, Mr. Verrill has dedicated a series of books. In these, the fifth and sixth volumes, he tells us about fishes that walk, beasts that lay eggs and a great variety of other creatures which violate, in one way or another, our ideas of what animals are and do.

They violate *our ideas;* that is significant. Though Mr. Verrill labels them strange, or misfits, most of these animals belong to ancient lineages which were established on earth ages before man began to decide what was queer and what was commonplace. It is we who marvel, not they that are essentially marvelous; our amazement at their forms and ways is a measure of our unfamiliarity with the biologic world. In so far as Mr. Verrill's books reduce that unfamiliarity and contribute to understanding, they perform a good service. If they merely intensify our willingness to marvel, they are likely to do harm.

C. L. F.

[1] *Strange Fish and Their Stories.* By A. Hyatt Verrill. Illustrated. xix+220 pp. *Strange Animals and Their Stories.* By A. Hyatt Verrill. Illustrated. 235 pp. $2.50 each. L. C. Page Company.



PHYSICISTS WHO TOOK PART IN THE COSMIC RAY SYMPOSIUM

(1) H. A. Bethe, Cornell. (2) R. R. Brode, California. (3) A. H. Compton, Chicago. (4) E. Teller, George Washington. (5) A. Baños, Jr., Mexico. (6) M. S. Vallarta, M. I. T. (7) S. A. Goudsmit, Michigan. (8) J. R. Oppenheimer, California. (9) C. D. Anderson, Calif. I. Tech. (10) V. F. Hess, Fordham. (11) B. Rossi, Manchester. (12) W. Bothe, Kaiser Wilhelm Institute. (13) P. Auger, Paris. (14) W. Heisenberg, Leipzig. (15) T. H. Johnson, Bartol. (16) J. Clay, Amsterdam. (17) F. Ehrenhaft, Vienna. (18) W. F. G. Swann, Bartol. (19) S. H. Neddermeyer, Calif. I. Tech. (20) G. Herzog, Zürich-Chicago. (21) W. D. Harkins, Chicago. (22) H. G. Beutler, Chicago. (23) D. K. Froman, McGill. (24) M. Schein, Chicago. (25) C. G. Montgomery, Bartol. (26) G. Grötzinger, Vienna-Chicago. (27) L. W. Nordheim, Duke. (28) E. O. Wollan, Chicago. (29) S. E. Forbush, Carnegie I. Washington. (30) W. M. Nelson, Duke. (31) V. C. Wilson, Chicago. (32) H. Jones, Chicago. (33) O. Godart, M. I. T. (34) A. Haas, Notre Dame. (35) M. A. Pomerantz, Bartol. (36) R. S. Shankland, Case. (37) C. Eckart, Chicago. (38) J. C. Stearns, Denver. (39) J. J. Hopfield, Toledo. (40) W. P. Jesse, Chicago. (41) B. J. Hoag, Chicago. (42) N. Hilberry, New York U. (43) F. R. Shonka, de Paul. (44) P. S. Gill, Chicago. (45) A. H. Snell, Chicago. (46) E. J. Schremp, Washington (St. Louis). (47) E. Dorshem, Chicago. (48) C. Holley, Chicago. (49) R. B. Sawyer, Centre College. (50) F. L. Code, Vancouver.

THE PROGRESS OF SCIENCE

CHICAGO COSMIC RAY SYMPOSIUM

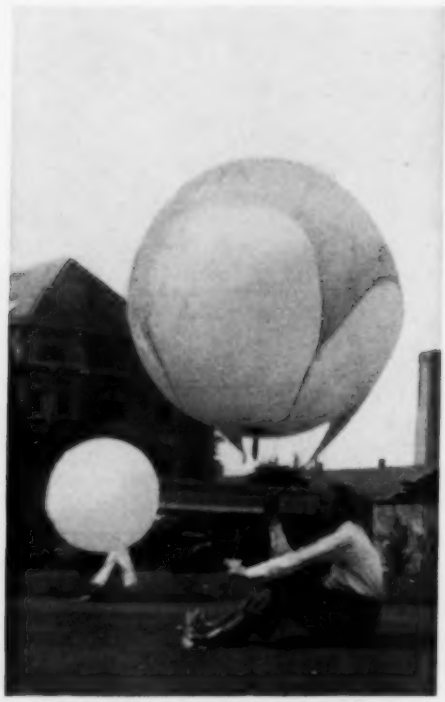
DURING the last week of June there was held at the University of Chicago a notable symposium on cosmic rays. A large proportion of the active students of cosmic rays throughout the world were in attendance. These included: Victor Hess, now of Fordham University, whose balloon experiments in Austria in 1912 established the existence of the rays; Carl D. Anderson, of the California Institute of Technology, who discovered positive electrons among his cosmic rays and found evidence for the presence also of the new sub-atomic particle, the meson; Werner Heisenberg, of Leipzig, of quantum theory fame, who has done much in interpreting the action of cosmic rays; W. Bothe, from Heidelberg, and Bruno Rossi, from Padua, whose counter tube experiments have demonstrated the corpuscular properties of the rays; and leading representatives of other research groups from England, Holland, Canada, Mexico and the United States.

In modern research in the fundamentals of physics, the study of cosmic rays has occupied less attention than that of the structure of the nucleus of the atom or of the interpretation of spectral lines. Its students, however, believe that in cosmic rays we have the most effective tool for studying the components of atoms and how their nuclei are put together. Just as when the study of x-ray spectra helped us to solve the problems of the electronic atmosphere of atoms, so, it is hoped, the study of cosmic ray processes will clarify our understanding of radio-activity and other nuclear processes, and lead to the next great advance beyond the quantum theory. It was perhaps this feeling of the great intrinsic importance of their investigations which accounted for the concentrated interest and attention on the part of the galaxy of notable physicists during their four-day session.

Among the major findings reported may be mentioned conclusive evidence for the existence of mesons, new data with regard to their remarkable penetration, evidence that they can be formed as rays in the atmosphere by the impact between energetic particles, and apparently also of their spontaneous disintegration by a kind of radioactive process. Neutrons are much more abundant in cosmic rays than had previously been suspected, though the less massive neutrettos and neutrinos remain on the list of mere suspects. It now seems probable that the incoming cosmic rays consist of protons, and that these come from our own galaxy, with energies of from a billion to a million billion electron volts.

It is noteworthy that the subject of how the cosmic rays are produced, which was the center of attention a few years ago, occupied no more than five minutes of the twenty-five hours of busy sessions of the symposium. Their origin remains a mystery. Of more immediate concern has been the problems of finding the composition of the rays as we observe them on the earth and of learning what the rays do as they pass through matter.

First to be identified among the cosmic rays in our atmosphere were electrons and photons. Pierre Auger of Paris reported the remarkable observation that these particles frequently occur in widely spread showers, sometimes as far as a thousand feet apart, all appearing to originate from the same parent ray high in the atmosphere. The energy of the original ray which gives rise to such a shower of photons and electrons must sometimes be greater than a million billion electron volts, far greater than any other known type of ray. Dr. Serge



PROFESSOR PIERRE AUGER
OF THE UNIVERSITY OF PARIS, ASSISTING IN A COSMIC RAY BALLOON FLIGHT FROM STAGG FIELD, UNIVERSITY OF CHICAGO, ON THE FIRST DAY OF THE SYMPOSIUM.

Korff, of the Bartol Research Foundation, described a series of his high altitude balloon flights in which, associated with these photons and electrons, he found the existence of a large number of neutrons. For detecting the neutron rays he used the novel technique of filling his counting tubes with a gas containing boron, which has the remarkable property of absorbing neutrons and becoming radioactive. The detection of the neutrons is then made possible by observing the disintegration of the boron atoms. Korff observed that the rate of increase of neutrons is even more rapid with altitude than is the increase in the main body of cosmic rays. It appears possible that the neutrons result from the disintegration of the nuclei of nitrogen atoms when struck by the primary cosmic rays that come in from outside the atmosphere.

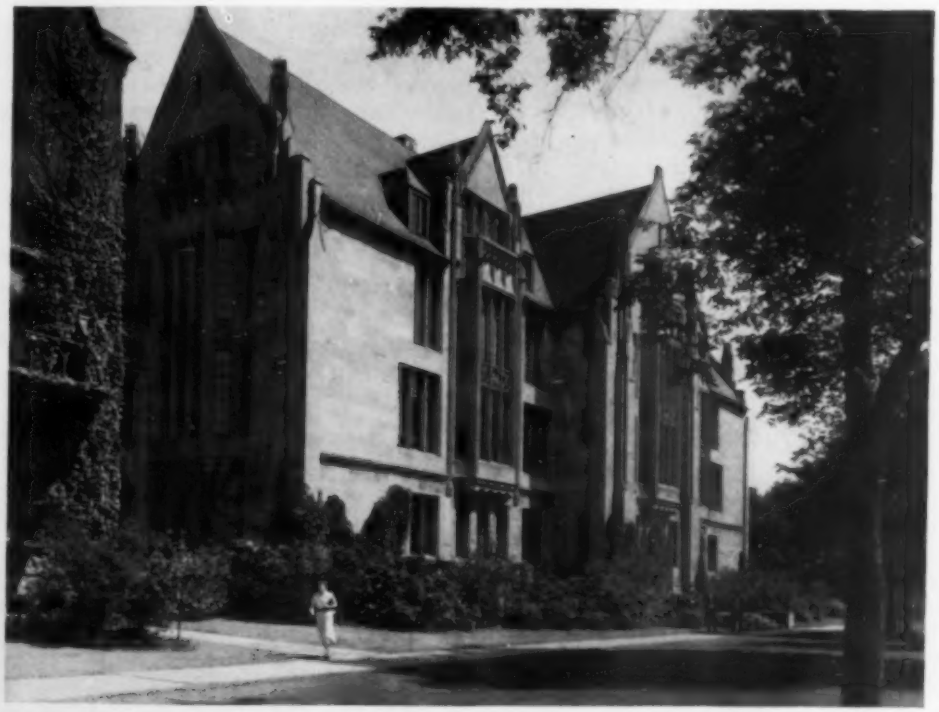
Carl Anderson and Seth Neddermeyer, of the California Institute of Technology, reviewed their now classic experiments, which show in a cloud chamber between the poles of a powerful electromagnet the distinctive paths followed by the various types of cosmic ray particles. Positive and negative electrons were made evident and new and more conclusive evidence was presented for the existence of mesons. Robert Brode, of the University of California, added the results of somewhat similar studies in which he was able to count one by one the ions along the paths of these various particles. W. Bothe, of the Kaiser Wilhelm Institute at Heidelberg, added strong evidence of a similar type. If there had been any doubt of the reality of the meson, none of the investigators present felt that the evidence could now be questioned.

Volney Wilson, of the University of Chicago, reported measurements of cosmic rays made in various underground locations, down as far as 1,600 feet below the ground, which revealed the existence of the penetrating meson at least to a depth of 400 feet. On the basis of his own new experiments at great depths, J. Clay, of Amsterdam, suggested that below 400 feet the predominate form of radiation may be of a different type, namely, neutrinos, whose existence has for several years been suspected. Whether this view is correct remains to be answered by further experiments.

It has been more difficult to learn the composition of the rays which come into our atmosphere from outside beyond the reach of our laboratory instruments. Because of the manner in which the earth's magnetic field bends the paths of these incoming rays, it has been known for some time that they are electrically charged and that this charge is

predominately positive. The physicists from Bartol Research Foundation—W. F. G. Swann, T. H. Johnson and Mr. and Mrs. C. D. Montgomery—brought forward cogent experimental and theoretical arguments favoring the view that these incoming rays are protons, the positive nuclei of hydrogen atoms. Heretofore most physicists have doubted the adequacy of protons as an explanation for cosmic ray effects because it was supposed that particles as heavy as these could not produce the photons and electrons that are found so abundantly among the cosmic rays at high altitudes. A discussion of the mechanism of the production of mesons, however, by Werner Heisenberg, of Leipzig, indicated that very probably protons should be more important in affecting atomic nuclei than should any of the lighter types of particles. On this view not only the meson but photons, electrons and neutrons, as well, would all be emitted when a proton coming to the atmosphere from the outside would make a close collision with an atomic nucleus.

Where the rays originate is a question whose answer is being sought by a group of investigators whose work was reported by A. H. Compton. This study concerned itself with an investigation of the relative intensity of the cosmic rays in the northern and southern hemispheres, a series of measurements being made on board a ship plying between Canada and Australia and Tasmania. If the rays came from beyond the Milky Way, because of the motion of the earth with the rotation of the Milky Way, more of these rays should be received on the front than on the back of the earth. The



BERNARD A. ECKHART HALL FOR PHYSICS, MATHEMATICS AND ASTRONOMY
WHERE THE COSMIC RAY SYMPOSIUM WAS HELD, AND WHICH, WITH RYERSON LABORATORY (LEFT FOREGROUND), HOUSES MOST OF THE PHYSICS RESEARCH OF THE UNIVERSITY.

front in this case is the northern hemisphere. The result of three years' observation was to indicate no difference between the rays received in the two hemispheres within a probable error of about one part in a thousand. Since an effect of about one part in two hundred was anticipated due to the earth's motion, this seems to mean that the rays share the rotation of the Milky Way and, hence, are presumably a part of our own galactic system. Though this result supports the conclusion drawn last year from a study of the daily changes of cosmic rays, the result is still somewhat uncertain, pending further theoretical and experimental investigations. Tentatively at least, however, the "cosmic" rays that we receive seem to be of no more remote origin than are the stars that belong to our galaxy.

One wishes there were time to consider, as M. S. Vallarta and Victor Hess have done, the way in which the cosmic rays are affected by the magnetic field of the earth and apparently likewise of the sun. In these effects lies an important method of determining the energy of the rays as they approach the earth, which varies from about a billion to a million billion electron volts.

As was to be expected at a stage of investigation where the experiments are not yet highly refined, there were some disagreements as to the exact nature of the data. Most prominent of these was that with regard to the existence of a penetrating neutral radiation which would give rise to penetrating mesons in lead. Experimental evidence put forward by W. Bothe was questioned by Bruno Rossi and by Pierre Auger. An hour's discussion of the point by the various investigators showed that further information is needed before the question of the existence of this neutral penetrating radiation can be considered confirmed.

The only other question of major disagreement was that of the name which should be applied to the particle of intermediate mass. This has been called at various times a heavy electron, a barytron, a yukon, a mesotron, a mesoton and a meson. A poll of the assembled experts showed an approximately equal number favoring the name mesotron and meson. Partly because the European investigators seemed unanimously to favor the word meson, the present writer is likewise adopting that word in order to prevent the confusion of tongues.

The accomplishments of the symposium are not to be measured in terms of definite new conclusions which were reached. Its main significance lies rather in the fact that it focussed attention on the important possibilities of the study of cosmic rays. The true effects of the conference will thus not be felt until those who were present have had time to express in their own work their reaction to the new ideas and the stimulating discussions.

A. H. Compton
University of Chicago

THE STANFORD UNIVERSITY SYMPOSIUM ON THE CELL AND PROTOPLASM

It is seldom that I have attempted to write anything, however brief, which seemed to bristle with the difficulties that I now sense in acceding to the request of The Scientific Monthly for a report on this symposium. To any in attendance the difficulties would not be hard to visualize. But first let me describe in a very general and, I fear, a rather superficial fashion the intent and form of the symposium.

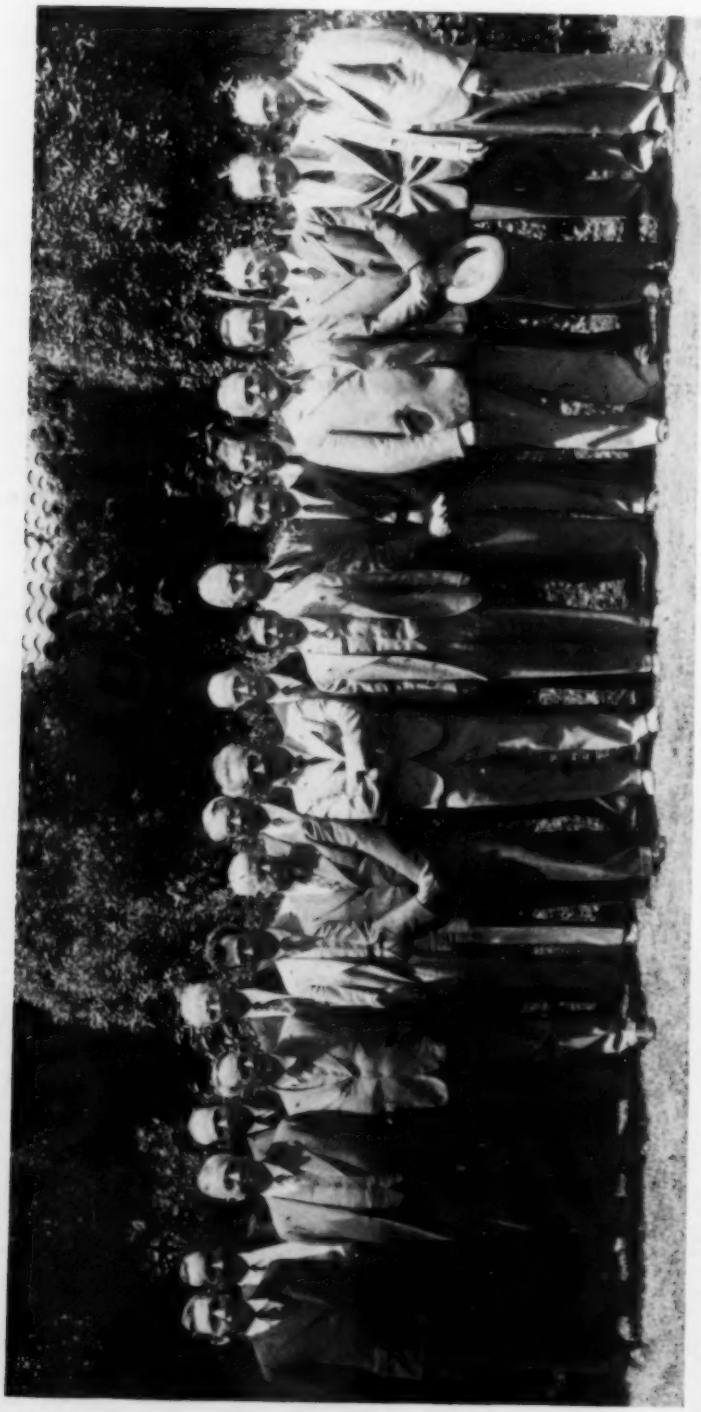
It was organized by Professor C. V. Taylor, dean of the School of Biological Sciences, and his immediate associates

with the purpose in mind of commemorating in appropriate fashion one of the great epochs in the history of the biological sciences — Schleiden and Schwann's enunciation of the cell theory. As is true of scientific discovery generally, this basic concept did not spring in adult stature from the head of a single Zeus. Many biologists, some of whom have been almost forgotten in the flight of the centuries, contributed their part. But without doubt it was Schleiden and Schwann who finally drew together the researches of their many predecessors and presented to the world of learning a final statement of the cell theory in a systematic and comparative form with a full appreciation of its fundamental implications. One can safely hazard the thought that had Schleiden and Schwann not been in a writing mood in the year 1838, others would certainly have presented the same theory in an equally or perhaps an even more acceptable form within a year or two. The fruit was ripe and it was only a question of seeing the trees, recognizing the maturity of the fruit and picking the crop. I have never ceased to be enraptured by the constantly recurring observation that most of our great discoveries in science are announced almost simultaneously from several different laboratories by men whose approach to the problem has been entirely independent. However, the explanation is simple, for it is all a part of the endless process of the evolution and fruition of thought. To those of us in attendance at the symposium evidences of this simple fact came again and again.

The introductory address, historical in character, was presented by Professor E. G. Conklin, of Princeton University. Unfortunately space does not permit us to speak of this in detail nor of the fifteen addresses that followed in the next five days. Perhaps it is sufficient to mention that by a gradual transition we passed from consideration of the grosser structure of living things to a treatment of developmental and environmental factors, to microorganisms, over the bridge which possibly stands between the animate and the inanimate—the viruses, on to the active constituents of living things and finally to the larger molecules resident in protoplasm.

It is fortunate that the papers will be published (as a monograph by the American Association for the Advancement of Science) so that it is needless to do more

THE SCHOOL OF EDUCATION BUILDING (RIGHT) WHERE THE STANFORD SYMPOSIUM CONVENED



MEMBERS OF THE SYMPOSIUM ON THE CELL AND PROTOPLASM

Back row: ALBERT TYLER, WILLIS H. JOHNSON, C. H. DANFORTH, E. G. CONKLIN, R. G. HARRISON, ROBERT CHAMBERS, A. J. HAAGEN-SMIT, V. C. TWITTY, W. M. STANLEY. *Front Row:* L. V. HEILBRUNN, C. A. KOFOID, H. S. JENNINGS, S. C. BROOKS, C. M. CHILD, A. SZENT-GYÖRGYI, D. M. WHITAKER, L. R. BLINKS, C. V. TAYLOR, RICHARD GOLDSCHMIDT, E. W. SCHULTZ.

than mention the speakers by name: E. G. Conklin, Robert Chambers, I. W. Bailey, H. S. Jennings, Richard Goldschmidt, C. M. Child, R. G. Harrison, C. A. Kofoid, C. B. van Niel, W. M. Stanley, H. Theorell, F. W. Went, A. Szent-Györgyi, O. L. Sponsler, L. V. Heilbrunn, J. D. Bernal.

By still another easy transition the meetings, born out of the Stanford University meetings of the Pacific Division, American Association for the Advancement of Science, passed on into the sessions of the National Colloid Symposium, which followed immediately after.

One outstanding result of the symposium was to leave with all of us a vivid impression of the essential unity of the sciences. It is all too easy for us, when surrounded by increasing evidence of diversification and specialization in research, to mumble the disheartening and misleading phrase, "more and more about less and less." Seldom have I taken part in a scientific meeting where one was made more acutely aware of the striking interdependence of all the sciences. Biologists, chemists and physicists, speaking the same language, drew fully upon the resources of each to gain a deeper understanding of the world of nature.

From it all I believe that we gained several suggestions of very great value: that the animate and the inanimate constitute a continuum; that the concept of structure, so long applied to the atom, to the molecule, to the cell and to the organism, may well be extended to the society in which we are but structural units; that whether we be molecules or men we are what we are and we do what we do because of two fundamental factors—our innate qualities and our environment. I would not dare to suggest that this exhausts the list of significant gleanings, but to me they constitute the

"Biology and its Makers," 1910, Henry Holt & Co.

THEODOR SCHWANN, 1810–1882

MATTHIAS JACOB SCHLEIDEN, 1804–1881

most impressive contributions of the symposium.

And now to conclude with less tangible and perhaps rather sentimental considerations. Some of us who still like to think that we are numbered among the younger generation of biologists and biochemists will not soon forget the stimulating contacts and refreshing experiences that were ours as we saw, heard and chatted with the distinguished elder statesmen of science (younger statesmen also) and shared our lot with our many countrymen and visitors from abroad. Unquestionably, this was probably the most memorable scientific gathering that we have known on the Pacific Coast and it is to be hoped that the bridge now reaching to the Atlantic Coast and Europe will bring to us many fresh contingents of our fellow scientists.

The meetings steadily increased in attendance as the week progressed until, as the last day was reached, the facilities of the large Memorial Theater had to be drawn upon. The periods of discussion which followed the papers were lively and vigorous. I think they would have been a delight to Schleiden and Schwann and to the host of others whose contributions to science constitute the warp and the woof of such symposia.

J. Murray Luck
Stanford University

THE CENTENARY OF T. J. BURRILL

On April 25, 1939, the one hundredth anniversary of the birth of Thomas Jonathan Burrill was celebrated by the University of Illinois, where practically his entire professional life was spent. During his long connection with the university, from 1868 to 1912, he served in various administrative capacities, published the results of numerous researches, and carried at times a heavy teaching schedule. Under him were developed a number of students who won recognition in various fields of botany, some of whom are still active.

Burrill was born in Pittsfield, Massachusetts. The family moved to Illinois when he was nine years of age. He helped his father on the farm, attending and later teaching school during the winter months; he prepared for college at Rockford High School, which he entered at the age of 20, and graduated from the State Normal University in 1865.

During the period from 1865 to 1868 Burrill held the position of superintendent of the Urbana public schools. During the summer of 1867 he acted as botanist accompanying Major John W. Powell on his expedition to explore the Grand Canyon of the Colorado and surrounding regions. In 1868 Burrill was called to the Illinois Industrial University and in 1870 was made professor of botany and horticulture.

Regarding his activities in the early days of his service in this institution, now the University of Illinois, a friend is quoted as saying:

> He taught most of the days, was horticulturist to the experiment station, planted with his own hands or saw to the planting of most of the trees on the campus, after he had laid it out for treatment, wrote reports, lectured here and there, served on innumerable committees, collected specimens up and down the state, and, lest some moment of his time should be unoccupied, was charged by the board with the sale of mules, whose labors on the south farm showed that they were not so able to stand the strenuous life as he was.

Two notable contributions to the teaching of botany are to be definitely credited to T. J. Burrill. He was the first to teach plant pathology, which he took up as part of his course in botany as early as 1873, two years before Farlow at Harvard, and he was the first in this country to use the compound microscope

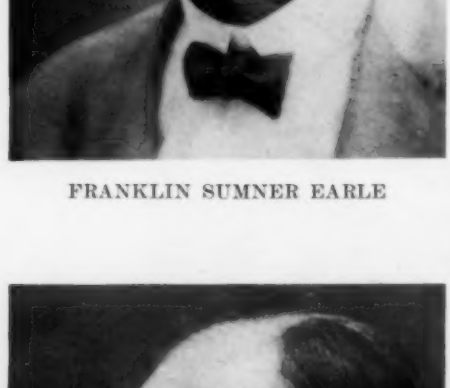
in teaching undergraduate courses in botany.

Burrill's great contribution to science, the discovery and demonstration of the first bacterial disease of plants, came as a result of patient and thorough work on what was then a major problem for the fruit-growers of his state. The "blight" of pears and apples had been the subject of much concern and speculation for many years. In 1878, just ten years after his first connection with the university, he presented to the state horticultural society a paper reporting his preliminary studies, in which he described the organisms seen in the tissues as "minute oscillating particles." The next year he reported his success in transmitting the disease by transferring the exudate from diseased plants to the bark of healthy trees. In the report he used, though with great caution, the word "bacteria," adding: "Does it not seem plausible that they cause the subsequent apparent change? . . . So far as I know the idea is a new one—that bacteria cause disease in plants—though abundantly proved in the case of animals."

THOMAS JONATHAN BURRILL

Further careful work followed, and in 1882 the bacterial organism was described and named. In subsequent years he worked on several other bacterial dis-

FRANKLIN SUMNER EARLE



ARTHUR BLISS SEYMOUR

eases and on various fungous diseases of apples, potatoes, corn and other crops. A cryptogamic flora of Illinois was projected and two monographs were published, one on the rusts and the other on the mildews.

It is fortunate for Burrill's reputation that he made this great discovery early in his connection with the university, for as time went on his energies were increasingly devoted to administrative and related duties. Of this Edwin F. Smith said with characteristic emphasis in an article published soon after Burrill's death:

> In America we have a peculiar way of treating all those who have demonstrated the possession of research ability of a high order, which may be designated as a method of extinction by promotion. As soon as a man becomes conspicuous through his researches, boards of control find other things for him to do, more in keeping with their ideas of efficiency and eternal fitness, and he ceases to contribute further except perhaps very indirectly, to the advancement of science. Professor Burrill was no exception to this rule.

During the first two decades of his connection with the university he made his great contributions to the science of plant pathology and trained four men who attained places of distinction in the fields of plant pathology and mycology, Earle, Seymour, Clinton and Waite. No attempt to detail the work of Burrill or any of the others is made here, since sympathetic biographical sketches[1] by personal friends are available for Burrill and three of his students. Although the fourth has been formally "retired" since 1935 there is happily little prospect of his becoming the subject of such a sketch for many years.

F. S. Earle, who was a student of Burrill's from 1879 to 1883, was at various times connected with the Kentucky, Mis-

[1] Burrill, *Phytopathology*, 8: 1–4; Earle, *Phytopathology*, 20: 923–929; Seymour, *Mycologia*, 26: 279–290; Clinton, *Phytopathology*, 28: 379–387, and *Mycologia*, 30: 481–493.

sissippi and Alabama Experiment Stations, with the United States Department of Agriculture and with several institutions in Puerto Rico and Cuba. More than once he engaged in commercial fruit production. He is remembered both for his contributions to systematic mycology and as a leading authority on the diseases and culture of tropical plants.

A. B. Seymour, who studied and worked with Burrill from 1878 to 1883, was essentially a mycologist. So abundant were his collections during the period of his work in Illinois, and so carefully were they preserved that portions of them are still used as "class material" by the Botany Department of the University of Illinois. The greater part of his life, 1883 to 1933, was spent in the Farlow Herbarium at Harvard, and his chief monument is the "Host Index of the Fungi of North America," the first of its kind.

G. P. Clinton was at the University of Illinois as a student and investigator from 1886 to 1900. He followed Seymour to Harvard and in 1902 became botanist of the Connecticut Experiment Station, which position he held until his retirement in 1937. Most of his scientific contributions are contained in the publications of that station. From 1915 to 1929 he was also lecturer and associate in the Department of Botany at Yale. This long residence in New Haven was broken by two major scientific assignments, one in Puerto Rico to study diseases of coffee, and one to Japan for the collection and study of parasites of the gipsy-moth.

M. B. Waite graduated under Burrill in 1887 and spent almost his entire professional life with the United States Department of Agriculture. Here, he was for many years in charge of the work on fruit diseases. In 1898 he made one

GEORGE PERKINS CLINTON

DR. M. B. WAITE

of the great phytopathological discoveries of all time, namely, that bacteria which cause plant disease may be carried by insects. Appropriately enough this discovery was made with regard to the same disease in connection with which Burrill had made his great contribution nearly twenty years earlier.

NEIL E. STEVENS
UNIVERSITY OF ILLINOIS

THE SEVENTH ASSEMBLY OF THE INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS

ONE of the most significant scientific congresses to be held in this country will be the Seventh Assembly of the International Union of Geodesy and Geophysics to be held in Washington from September 4 to 15. Over 500 delegates and guests are expected in attendance. To date delegates will represent 23 countries and over forty universities, colleges and scientific institutions in this country.

The International Union of Geodesy and Geophysics is composed of seven associations. These seven associations are concerned with geodesy, seismology, meteorology, terrestrial magnetism and electricity, physical oceanography, volcanology and scientific hydrology. Unlike the usual meetings of technical societies, the program of the International Union consists largely of reports of commissions, discussion of agenda and the adoption of programs of research in the various fields of geophysics involving international cooperation. Many important communications of interest to geologists will be presented, however, and significant progress will be reported concerning investigations in the fundamental problems of the earth sciences, such as those dealing with structure of continents and ocean basins, gravity determinations and seismology. George Washington University will be headquarters for the assembly.

While there will be meetings of the several associations and commissions on Monday, Tuesday and Wednesday, the first general assembly, followed by a reception, will be held on Wednesday evening, September 6, at which the president, Dr. D. la Cour, will deliver an address.

A public lecture by Brigadier-General H. St. John L. Winterbotham, general secretary of the Union, on "Round the World with Geodesy" will be given on the evening of September 8 in the auditorium of the Carnegie Institution. On the evening of September 13 there will be a public address in the hall of the Department of Commerce by Dr. B. Helland-Hansen, of the Geophysical Institute at Bergen, Norway, on "From the Mexican Gulf to the Arctic Sea—the Gulf Stream System and Its Significance."

The final general assembly will be held on September 16 in the new hall of George Washington University. The American Geophysical Union, with the cooperation of the National Research Council, are the official hosts for the Washington Assembly. The arrangements for the assembly have been carried out through the work of nineteen committees and subcommittees. The chairman of the organizing committee is Captain N. H. Heck, of the U. S. Coast and Geodetic Survey.

The meetings of the Union are held at three-year intervals, the last meeting being in Edinburgh in 1936. There is probably no scientific association that covers a wider field of interest than the International Union of Geodesy and Geophysics. Perhaps in no other field are the problems of science so dependent upon international cooperation as in that of geodesy and geophysics.

HARLAN T. STETSON

WILLIAM BOWIE MEDAL OF THE AMERICAN GEOPHYSICAL UNION

THE WILLIAM BOWIE MEDAL

THE William Bowie Medal, endowed by friends and coworkers of Dr. William Bowie, established by vote of the executive committee of the American Geophysical Union on March 1, 1939, in accordance with the deed of gift, is to be awarded for distinguished attainment and outstanding contribution to the advancement of cooperative research in fundamental geophysics. The medal was designed by Margaret Fleming Nebeker, of San Francisco, and the dies were engraved by B. Basch, of Washington. The award of this medal is to be made annually or less frequently upon authorization by the executive committee of the Union.

The first medal, which was struck off by the hydraulic press of the United States Bureau of Engraving through the courtesy of the director, A. W. Hall, was presented to Dr. Bowie at the general assembly of the American Geophysical Union on April 28, 1939, by President Richard M. Field. In his citation President Field said:

> It is particularly fitting that the first award of this medal should be to the man whose name the medal bears. It is not necessary here, among your intimate friends and colleagues in geophysics, to refer specifically to your long list of scientific accomplishments and honors. But we do feel that in presenting you with the first imprint of this medal that has been created in your name, and that of the organization for which you have worked so long and so lovingly, we are not handing you merely a bit of stamped and engraved metal, but rather a powerful talisman of those human forces, affection, esteem and tradition so fundamental to the spirit of progress. It is sincerely hoped that in the years to come this medal, through its future awards, will continue to promote and to recognize that spirit of helpfulness and friendliness in unselfish cooperative research which you have so bountifully displayed.

SPECTROSCOPY IN THE REGION OF RADIO FREQUENCY

An extension of the field of spectroscopy down to the region of radio frequency has been developed by a group of physicists at Columbia University. The group consists of Dr. J. M. B. Kellogg, Dr. P. Kusch, Dr. S. Millman, Professor I. I. Rabi and Mr. Norman F. Ramsey, Jr., all of Columbia, and Professor J. R. Zacharias, of Hunter College. This development, which has taken place over a period of two years, has reached the point where accurate spectroscopy can be done on lines the frequency of which is less than a thousandth of the natural frequency width of ordinary spectral lines.

This new field of micro-spectroscopy can measure energy intervals which are 10^{-5} of the smallest energy intervals measurable by ordinary optical spectroscopy.

In the new method the effect of the radiation is observed not by analysis of the radiation but by observing the effect on the atom or molecule. This is made possible by the use of atomic and molecular beams. A narrow stream of atoms or molecules limited by slits .01 mm wide is bent first in one direction by means of an inhomogeneous magnetic field, and later by means of a second such field, oppositely directed, is bent back again to strike a detector which is capable of measuring the number of atoms which reach it. The second bending will just balance the first, provided the atom or molecule of the beam is in the same state in both fields. If, however, in the region between the two magnetic fields the atom or molecule should undergo a transition to a different state, one bending will not cancel the other and the beam will miss the detector. A transition in state can be brought about if the atom or molecule absorbs or emits energy. In these experiments the atoms or molecules are caused to absorb energy from, or emit it to, an oscillating magnetic field between the two inhomogeneous magnetic fields, this absorption or emission taking place only at very definite frequencies of the alternating field corresponding to frequencies of the atomic or molecular systems. The spectrum "lines" correspond to the field frequencies which cause the beam to miss the detector. These frequencies in the experiments are in the range of short and very short radio frequencies.

If a constant magnetic field is superimposed on the oscillating field the Zeeman effect of the lines can be studied.

This method has been applied to the accurate measurement of the magnetic moments of a large number of nuclei, including the proton and the deuteron, the isotopes of lithium, beryllium, the isotopes of boron, nitrogen and other nuclei. These measurements compare in directness and accuracy with measurements that may be made of the magnetic moment of an ordinary permanent bar magnet. They arrive at results that lie far beyond the reach of ordinary spectroscopic methods. An important result of the experiments with the hydrogen, deuterium and hydrogen deuteride molecules has been the discovery that the deuteron is not spherically symmetrical in shape but elongated along the spin axis.

I. I. Rabi

Columbia University